VARLEY

ON OPTICAL

DRAWING INSTRUMENTS.

A TREATISE

ON

OPTICAL DRAWING INSTRUMENTS,

BY

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ALSO,

A METHOD OF PRESERVING PICTURES IN OIL AND IN WATER COLOURS.

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ON OPTICAL DRAWING INSTRUMENTS.

The efforts that are being made to draw public attention to the means of improving their taste in the fine arts, and also in the collateral arts of design, would alone render a knowledge of such optical instruments as can aid those arts very desirable; but since to these is added the splendid discovery of the Daguerreotype, which only exists by means of the Camera Obscura, aided by Iodine, Bromine, &c., a correct knowledge of those instruments becomes a public desideratum.

To supply that defect, the following treatise is offered to the public in which the endeavour has been to make the subject as plain to the users of such instruments as to the makers of them:—

The Instruments treated of are the

Camera Obscura in its various modifications by which it is adapted to the different purposes of the Daguerreotype and drawing from nature.
Wollaston's Camera Lucida.
Varley's Plane Reflector.
Lorimier's Transparent Planes.
Varley's Graphic Telescope and Graphic Microscope.

First explaining the faults and defects incident to them for the purpose of showing how those faults may be either avoided, lessened, counteracted, or completely cured.

CAMERA OBSCURAS

Have been much the longest known to the public, and they have been usually made with single or uncorrected lenses, therefore, the action of single lenses will be first shown.

The very beautiful image of any view or object which a good convex lens can present in a darkened chamber (Camera Obscura) has always been a feature of general interest to the lovers of fine art.

Yet the Cameras we meet in the market are very imperfect, the more efficient ones seem to have been produced by private efforts. This want of zeal, in either the makers or the users, has left an unexpected result, for scarcely any other instrument so excellent in its capabilities and so long known has had so little use made of it; but some of the causes that conspire to retard its use will be shown farther on.

NATURAL CAMERA.

If a small hole *a* fig. 1 is made in one end of a box, otherwise quite dark, rays of light *c c* proceeding either from various objects, or different parts of the same object will pass through the hole to a white surface placed at *b b*, and these pencils of rays will form images of the objects from which they came, and if the surface *b* is quite upright the picture that is produced will be perfectly correct in form and perspective, because the angles within are similar to those without. This picture will be as much smaller than the original, as the distance *a b* is less than the distance *a c*, consequently lengthening the distance *a b*, will enlarge the picture in the same proportion. The smaller the hole at *a* the more distinct will be the picture, till it admits so few rays, that the images become invisible; while, on the contrary, if the hole is made so large as to admit plenty of light, the picture will lose all distinctness; such Cameras, on account of one or other of these defects, are therefore useless.

But place a convex lens in the enlarged aperture *a* fig. 2 whose focus will extend to *b*, it will make all the rays of each pencil or hole full to converge so as to meet together, and thereby form luminous points on every part of the surface *b*, and these points will form bright and distinct images of all the objects from which they came.

That a convex lens will give images at its focus is a fact generally known and admitted. I will, therefore, show the circumstances attending the formation of such images.

If the objects we wish to represent are accessible, any lens of moderate focal length can be placed so as to give images of them of any required size. When the distance *a b* equals *a c* the image will be as large as the object, if *a b* is one quarter the distance of *a c* the image will be one quarter the size, and so on; consequently the images of very distant objects are always much reduced, they being exactly as much smaller as the focus of the lens is shorter than the distance of such objects; and the only means of obtaining larger images of them is by using lenses of longer foci.

RULE FOR REDUCING IMAGES AND FINDING THE OPPOSITE FOCUS OR PLACE OF THE OBJECTS.

In fig. 3 the solar focus of the lens *a* is at *b* or *c*. To make the lens give an image as large as the original, the object must be placed at the double focus or twice as far as *c*, at the mark 1, the lens will then project its image twice as far as *b*, at the lower mark 1'.

Then since the lens would project the sun's image only as far as to *b*, it will be evident that the working foci of the lens for all images under the real size must fall somewhere between *b* and 1', having only the length of one focus for their range, although the place of the objects may vary from the point 1 to an infinite distance. The solar focus *c* is the starting point or zero, and not the lens: if we double the distance of the object by placing it at 2, the image will be formed half way between *b* and 1', and half the real size, there being three foci on one side and three half foci on the other. Now, as often as we double the distance from *c*, so often will be halved the remaining distance of the image from *b*; hence, from an object at 4, the image would be at one quarter, if from 8 the image would be one-eighth from *b*: now, suppose the object 1000 foci distant, its image will be only one-thousandth part of a focus beyond *b*; then suppose another object 2000 foci distant, a most enormous difference in the places of the two objects, yet the places of their images will differ but one-two thousandth part of a focus, and we shall scarcely see any difference in their distinctness on the screen: this explains why the adjustment of a telescope scarcely requires any change for observing two or more very distant objects, although the real distance between them may differ almost infinitely. To state this in few words for practice; if you will reduce to one-eighth, place the object nine foci distant from the lens, and its image will be nine fractions distant, or one focus and one-eighth. If to one-sixteenth, place the object seventeen foci distant, and its image will be one focus and one-sixteenth from the lens, being seventeen fractions.

It may also be as well to state here the arithmetical mode of finding the place of any opposite foci. Measure the distance of the image from the lens, and multiply that distance by the distance of the solar focus, then divide that product by the difference of the two numbers, and that will give the place or distance of the object from the lens: for example, if the focus is eight and the image one-quarter focus beyond, its distance will be ten $10 \times 8 = 80$, divide by the difference, which is 2, and that gives 40 for the distance of the object; in fig. 3 the numbers from 8 to 136 are different examples.

CURVED IMAGES.

It was shown by fig. 1, that the hole in a dark chamber must give true images, because the rays having no focus proceed equally well to all parts of the flat surface; not so with a lens; it will render the images distinct, but they will all be formed at equal distances from the centre of the lens, which of course ranges them in a spherical surface, as *b' b'* fig. 4, and thus prevent their being adjusted to equal distinctness at the same time on the plane *b b*.

DISTORTED IMAGES.

Lenses project the lateral images smaller than the central ones, and that in an increasing ratio, so that the image of a square figure is formed somewhat like fig. 5, the thickness of the lens causes this, so that a very thin lens has very little of this fault, but put a lens to the eye to magnify a small square, the reverse distortion, in a much greater degree, will be produced, it will appear like fig. 6. Fig. 7 shows the action that causes this opposite distortion. Let *a* be the centre of an object; *bb* and *cc* equal distances from it. The two pencils *bb* being near the centre, suffer little deflection from the lens *d*, so that the pencils *ee* will arrive at the proper place to enter the eye at *f*, with the central pencil, and shew that part of the object nearly accurate, whilst the outer pencils *cc* suffering much deflection, the emergent pencils will be more deflected than they ought to be, by which instead of arriving at *f* under an angle that would give true proportion, they will meet the axis too soon, about *h*, where the eye must be put to receive them; consequently, if these pencils are produced, as by the dotted lines, beyond the object, they will give the enlarged view, *a*, *bb*, *cc* shewn by a dotted line, in which the portions *b c* will be much larger than *a b*.

ERRORS OF THE LENS.

When rays of light enter glass perpendicularly, they pass through it without changing their direction; when they enter obliquely, they are deflected, *i. e.* bent out of their course: hence, when parallel rays arrive at a convex lens, all except the middle ray will enter it more or less obliquely, and so be all bent towards the centre one, and their point of meeting is called the focus; but the outer rays are bent more than is due to the mere obliquity of the surface; so that those rays that pass near the circumference of a lens, will meet in the axis nearer than those that pass through the central parts as in fig. 8; the consequence is, that such rays cannot co-operate to form one spot or distinct part of an image: this confines us to the use of only so much of the central part of a lens, as can bring the rays which pass through it near enough together; by this we loose much light: this fault cannot be totally removed from a single lens, but it may be increased or diminished by change of figure: if the curves of the two surfaces differ as one to six, and the lens, placed like fig. 9, it may be considered as a lens bent around the focal point, for if a compass be placed on the focus *b*, and made to describe the dotted curve through the lens, it will divide it exactly into two lenses of equal power; so there will be in every part as much lens within the curve as beyond it; thus each part of the lens is equi-distant from its focus; consequently, this lens has the least error by figure, and will bring the largest portion of the sun's rays to one spot, and for that purpose it will bear a very large aperture.

But, inasmuch as this lens is better for direct pencils, so much is it worse for oblique ones, and enormously so if it have a large aperture; therefore, it cannot be employed for a Camera that requires a large field; for that purpose an equi-convex lens is better, and we must either submit to a small aperture, or else use a

COMPOUND LENS,

because the error by figure is reduced as the square of the number; thus, two lenses will have four times less, and three lenses nine times less error by figure: these will therefore bear a larger aperture, and so give much more light and better definition; although some light is lost by the greater number of surfaces. But another fault remains, namely,

COLOURED RAYS.

Glass deflects blue rays so much more than red ones, that a small camera lens, whose red focus is 27 inches, will have its blue focus at 26 inches, the two being one inch apart as in fig. 10, *b* the blue and *r* the red focus; we have, therefore, one inch range of adjustment from the red, through the yellow, to the blue, and which ever image we take, it will be burred or fringed by the other colours; this gives another reason for reducing the aperture, till the want of light obliges us to stop and submit to the remaining indistinctness.

ACHROMATIC LENSES.

Thus far faults are only lessened, not removed. Modern artists, however, have it in their power to make lenses that shall completely correct each others faults; and thus becoming Achromatic, will bear as large an aperture as we need to afford the requisite degree of light. The images thus obtained have a beauty and distinctness incomparably surpassing all others. But here I must show an error which some Photographers seem to have fallen into, through want of more accurate knowledge of Optics, and which seems to have led them to erroneous conclusions. They have used for their purpose object glasses, constructed as for telescopes, apparently not knowing that such are over corrected. It has been stated with fig. 10 that the longitudinal difference between the blue and red focus is $\frac{1}{27}$ part of the focal distance of the lens. The eye-pieces of astronomical telescopes consist of two lenses, each containing this fault, and these two quantities can only be cured by the object glass; it is, therefore, over corrected enough to include these two faults by protruding the blue focus beyond the true point of correction, in a quantity equal to that difference. The eye-piece of a day telescope contains four and sometimes five lenses, whose longitudinal errors have to be corrected by the object-glass; so that such object-glasses must have a large amount of over-correction. If such as these are used for Photographic purposes, we need not wonder at the difficulty of finding the chemical focus; for the image most visible to the eye with such a lens is between the red and yellow foci, while the blue has the most chemical action. It has been, as it were, groped after by trying to find what distance this chemical focus is beyond the visible one, and this has led those who have thought the lens to be correct, to conclude that the chemical focus is quite separate from the other and farther off, whereas the blue and chemical foci are naturally the shortest, and ought, therefore, according to theory, have been sought within or nearer than the visible focus.

OBLIQUE PENCILS.

However excellent a lens may be, the lateral images will not be so well defined as the central ones are; the rays of oblique pencils are unequally deflected, and that in an increasing ratio to their obliquity, and this fault increases with the thickness of the lens. In fig. 11, *c c c*, are rays proceeding from one point of a distant object; these, in passing through the lens, will be so displaced, that the focus of the outer portion *l*, will go on to *b'*; the middle only to *b*, and the inner portion *m*, will be much shorter, reaching only to *b"*; and yet it will have crossed the middle portion: here the inner portion *c m*, is much the worst; whilst in a cross direction, fig. 12, the rays of these portions suffer no displacement. To remove the worst part of this fault, a stop or aperture, *o o*, fig. 11, is placed above the lens; it allows the whole central pencil to pass, but begins to intercept the worst rays, and that more and more as they are more oblique. This lessening of the light towards the margin, is little or no harm for a drawing camera, but it will not do for the Daguerreotype, that needing the utmost equality of light.

DOUBLE ACHROMATIC LENS.

To remove the above defect more completely and retain equality of light, Mr. A. Ross, and other Opticians, who have paid much attention to this subject, use two achromatic lenses of the same focal length, but carefully figured to suit their particular place. Hence arises a great advantage, for the two lenses leave only a quarter of the fault to correct, and this remainder he cures by their position. In fig. 13, *a* and *a'*, are the two lenses; they are placed about one-third of their joint focus apart with a stop, *o o*, midway between: *c c'*, is an oblique pencil of rays coming from an object, these, in passing the first lens *a*, receive but half their convergence, and therefore have four times less fault. The side *c* of this pencil, in passing through the centre of *a*, suffers no damage; but the side *c*, passing through the margin, receives all the lateral action. But the stop *o o*, excludes all other rays except this pencil, which will enter the second lens *a*, exactly on the other side of the axis. Now the ray *c'* that has suffered all the action of the upper lens, will pass through the centre of the lower one free from any additional action; whilst the side *c*, that is yet free from action, will now have to pass through the margin and receive all the action of this lens: and thus, every ray of this pencil will have alternately changed its condition, so equally, that they will meet together and give a distinct lateral image; and this pencil passing through one side of the lower lens will extend a little further than it otherwise would from the centre; causing the curve *b b*, to be a little flatter. By thus making the two lenses larger than their working aperture, three important benefits are obtained; equal light, on every part of the picture, and equal definition; and this, doubling the thickness, counteracts the ordinary effect of thickness in the lens; so that the distortions arising therefrom is removed, and a tendency to the contrary fault slightly induced. But still the image is not quite flat, and therefore cannot be adjusted to equal distinctness on a flat surface.

CURVED AND DISTORTED IMAGES.

It has been stated that a lens forms its various foci, equi-distant from itself as a centre; a near object would therefore require to be curved like *p p*, fig. 14, in order to place all its parts equi-distant from the lens, and then only could its image be projected in the concentric curve *b' b'*; but the extremities of a flat object *c*, are farther from the lens than its centre is, and that in an increasing ratio. The lens therefore cannot project its image in the true spherical curve *b b*, but in the quickening one *q q*, fig. 15, somewhat like an oblate spheroid; and this error of curvature will be increased by the thickness of any single achromatic lens: for the ray or pencil *c*, fig. 15, instead of pursuing its dotted course towards *b*, will follow the course *s s*, which is nearer the centre than it should be. Hence, in addition to the fault of sphericity the marginal images are represented smaller than the central ones; the sides of a square will be curved into the form fig. 5; and when this deformity is added to the perspective deformity, occasioned by using lenses of short foci, we need not wonder at the larger Daguerreotype portraits having goggle faces. This distortion may be seen in the productions of all small cameras, and to the present time is allowed to deform the otherwise valuable productions of the Daguerreotype. These serious faults, first, sphericity of the image; second, the distortion of its form; and a third fault applying to the drawing camera, namely, that of a small part at a time only being luminous, are all curable by the same means, which will be shown farther on. Hence, distortion may be removed from the valuable productions of the Daguerreotype.

PERSPECTIVE DISTORTION.

Lenses of short foci produce very serious perspective deformity.

Let the circle fig. 16, serve for a bird's-eye view of the human head; *c*, the face. The image to be of a given size: *a*, the lens: *d d* will be the visible outline of the head, one-tenth less than the real diameter. Thus we shall have a face with a head proportionally too small for it; and in addition the nose at *c* will be one-fifth nearer to the lens than this false diameter, and one-third nearer than the real: it will therefore be one-fifth too large even for this false though apparent diameter of the head. Next, take a lens four times longer in focus, and place the head four times as far off to give the same sized image. Then *e e* will be the visible outline sixteen times nearer to the true size, and here the nose will be one-fifteenth too large. This is about the distortion that a twelve-inch lens will give to a portrait one quarter the size of life. With a two-feet lens, the sitter ten feet off, the nose will be one-thirtieth too large, or half the former fault; but the visible outline of the head will be four times nearer to the true size. But as one-eighth the real size is oftener used, the errors are sufficiently reduced by using a two-foot lens; because the sitters distance will be eighteen feet, and the greatest difference of distance from the nearest to the farthest visible part of his head, does not exceed four and a half inches. Yet with this lens, if the whole figure is taken and it reclines from you, there may be three feet difference between the nearest and farthest part. Then to this is added the optical distortion shewn in fig. 5, the central images or parts being always given too large for the lateral ones: hence we see the urgent want of a correction of these errors.

UNEQUAL ADJUSTMENT,

Arising from the different distances of objects causing their images to be projected at different distances from the lens, as was shown by fig. 3, will probably hinder us from ever obtaining a Daguerreotype portrait as large as life. Let the lens *a*, fig. 3, be eight inches focus, place the circumference of the head at sixteen inches, its image will be given full size at the opposite sixteen; the nose being four or five inches nearer will have its image projected to twenty-four inches distance, by which the convexity of this image will be double that of life, therefore, when by adjustment the circumference has been rendered distinct, the nose will be eight inches out of adjustment, and *vice versa*; on adjusting the plate only midway, both the near and far parts will be four inches out of adjustment, an amount of error which even the very longest foci could not reduce below two inches; therefore the image of a head as large as life cannot have all parts distinct at the same time.

But by reducing the images to less than the real size (and such figures are usually preferred) the approach to perfect distinctness is as the square of the reduction. Let the head be placed at forty inches, its image will be given at ten inches, and be one quarter the real size, and its convexity will be flattened down to one-sixteenth of the real thickness.

From a head at seventy-two inches the image would be one-eighth the size, and be flattened to one sixty-fourth; and this with midway adjustment brings all within the thirty-second part of an inch from the surface. In all farther reduction the images approach sufficiently near to flatness. To illustrate the flattening of the image more fully, fig. 17 will shew the elongated image *b* of a circle *c*, which is placed just within the double focus, and fig. 18 is a contrast to it, shewing the image when reduced. It is the image of a globe distant from the lens seventeen times the length of the focus; its diameter is therefore reduced to one-sixteenth of the original; and its thickness, instead of keeping its proportion *b f b*, is still farther reduced sixteen times, and thereby is flattened down to *ee*; so that whilst the image is only reduced sixteen times, its thickness has been reduced two hundred and fifty-six times. Thus, while a full sized image is projected in *alto releivo*, therefore cannot be adjusted to a flat surface; a reduced image is projected in *basso releivo*, becoming flatter and flatter as the reduction proceeds. Hence, landscape views, which are always reduced much more than this, have their various distances projected sufficiently near to the same surface to answer our purpose.

MEANS OF LESSENING FAULTS.

First, the spherical image, fig. 4 has been met (in mere exhibitions) by a concave surface; and secondly, by a cylindrical one, on which paper can be placed for drawing; as it removes much of the lateral want of adjustment. Thirdly, the bad definition of lateral images is reduced by lessening the aperture, and submitting to loss of light. Fourthly, (a plan which I have adopted myself) by means of the stop *o o* fig. 11, which only intercepts the damaged rays; by which more distinctness is gained than light lost. Fifthly, being at the expense of a lens much larger than the working aperture as *a* fig. 19, and placing the aperture at *o o*, far enough to make the oblique, or lateral pencils *c c*, use only the opposite side portions of the lens; making a great waste of aperture only to flatten the image in proportion to the difference between the dotted line and its concentric curve *b;* this was the chief purpose for which this plan was recommended; but Mr. Ross's double lens is greatly superior to it.

ACHROMATIC LENSES OF LONG FOCI

When used to produce the same sized images that are now obtained by short ones, will reduce most of the faults in proportion to the square of the length of their respective foci, hence this is the most obvious method of reducing many faults to an amount not worth caring for: and even when the means for total correction are provided; violent perspective can only be reduced by lenses of long foci. Thus, to enable a lens of short focus to take in a view of a near building, it must be directed to the middle of the object, as fig. 20, in which case the top is so much farther from the camera than the bottom, that it produces perpendicular perspective like fig. 21. Whereas a lens of only double that focus, if removed to double the distance, would be able to take in twice as much, and so allow the horizon to cross the middle of the area; a condition absolutely requisite to keep the building quite upright.

CORRECTING LENS.

In fig. 22 *a* is the camera lens, *a b* its working focus, place a plano lens *t*, of rather shorter focus just within *b*. Now, had this lens been placed close to *a*, it would have shortened the focus to half; and if it was slid towards *b*, it would keep lessening in its power of shortening the focus, till on *b* it would do nothing. But *b* is not the only focus; the various foci that give all the parts of the picture are ranged in the curve *b'b b'*: and the lens *t* is formed on the same curve, but placed the reverse way (the dotted line *t t*, fig. 9, showing that curvature as was explained in that figure) consequently only one ring of this lens can agree with one ring of the foci *b' b'*, and there it will not shorten them; that ring is the circumference, and all the rest of the lens *t*, is within the other foci of *a*; it will therefore shorten them more and more up to the central one; and it will do that in the degree exactly necessary to range all the foci in a *flat surface*. Thus all sphericity of the image being destroyed, the various foci will all correspond with any flat surface, and be all brought into correct adjustment at once. Secondly, all the pencils are rendered parallel to the axis, as shown at *g g g*, fig. 23; by which they all impinge perpendicularly upon the surface; which may be of consequence if it should be found to produce more equal chemical action on the daguerreotype plates. Thirdly, all distortion is corrected, for having shortened the central foci, those parts of the images derived from them will be correspondently diminished, and thus the form fig. 5 will be restored to a true square. Hence, a flat and truly correct image may be obtained for daguerreotyping; and fourthly, in addition to this, as a drawing camera, the whole picture will become equally luminous: for without the correcting lens the eye at *d*, fig. 24, can see quite luminous only a small portion *b b* of the curved picture, between the rays *e e*, which includes the area of the lens *a*; the rays forming the rest of the picture to *b'b'*, having passed aside as *e'e'*, and *e e*, fig. 22 invisible; a ground glass surface was therefore required for dispersing this light, thereby enabling the eye to take in a little of it and receive a dim view. But the lens *t* deflects the central rays of all the pencils into a cylinder parallel to each other; and the rest of the rays having crossed, diverge, after they have formed the picture; so a portion of every pencil converges toward the axis, as *v v*, by which the eye receives an equal quantity from every pencil; and the whole picture becomes equally luminous; no dispersing surface or grinding of the glass can, therefore, be of any use except for the purpose of receiving pencil marks; and consequently, really transparent paper becomes the best surface to draw on. Fifthly, it was shown by fig. 11 that the lateral images from one lens, though achromatic, could not be so distinct as the central ones; the inner rays of each pencil suffering too much refraction. But it will be seen in fig. 25 that the lens *t* receives these inner rays much the soonest, and with the most obliquity; so that they will be most acted on in a direction contrary to their fault, and be restrained from meeting the others so soon. They will, therefore, join them nearer to their proper focus *b*, instead of meeting short of it, and being dispersed over the area *l m*. Thus four eminent services are rendered by one correcting lens *t*; namely, equal or simultaneous adjustment over the whole surface: truth of form: better definition of the lateral images: equal visibility and brilliancy all over: and possibly, the pencils being all perpendicular, may produce more equal chemical action in forming daguerreotypes. I have shown by fig. 17 and fig. 3 that a daguerreotype image of a convex object cannot be had of the full size; but any flat object can: yet the image will have some distortion, like fig. 5. To obtain such a picture in perfection, would require another correcting lens *u*, fig. 22, to be placed before it; this lens would then receive the pencils from the flat surface quite perpendicular, as *g g g*, fig. 23; and present them on equal terms to the lens *a*, and then its spherical image would be corrected by the lens *t*, and presented quite flat to the iodized plate. This property of the lens *u*,—namely, its only taking pencils that are parallel to each other as *g g*, fig. 23, by which it refuses all perspective, giving only elevations of objects, would be a most valuable aid to camera lenses of short foci, could it be applied to convex objects; but it gives more precision to the foci on the object side of the lens; so it is not likely to answer for them. The cases that would require the lens *u*, do not often occur: we may, therefore, be content with the lens *t*; it either corrects or lessens every evil it has to contend with; even that shown in fig. 26, where the various distances of landscape objects causes their images to be projected unequally, or in some such curve as *b b b* fig. 26; *h h* is the plane usually adjusted midway between; the longer of these foci in passing through the correcting lens, are shortened in greater proportion than the others, on which account they are all brought nearer to a flat surface.

It is stated by some that the blue rays alone act chemically in Photography; if so, there would be no necessity for any of the lenses to be achromatic, two single lenses of the best figures placed, as in fig. 13, would serve. But those very Photographers still use achromatic lenses, which is a sufficient answer to their statement. Achromatic lenses may be corrected for Photography as accurately as for telescopes, by which they will bring the visible image exactly where the chemical one is, and render it easy to adjust. When a large angle or area is used for making Daguerreotypes, then the correcting lens ought also to be achromatic to prevent any lateral separations of the coloured rays; but with small angles it would scarcely be required, because the image is received so close to the correcting lens, that the coloured rays cannot be much separated, and on that account the drawing camera does not require it to be achromatic.

The very great size that will frequently be required for a correcting lens, will make it very expensive to be had in glass. But since plate glass, and convex glasses for mirrors, are in the market for ornamental purposes, it is only taking one of each and cementing them together; leaving a small aperture through which it may be filled with Canada balsam, or other highly refractive medium; and thus, clear lenses, of any size, may be had that will answer this purpose. And the notion of expense must be laid aside, seeing there is no other means of effecting these essentially important corrections.

The correcting lens adding another medium for the light to pass through, would probably require a little larger aperture in the camera lens, or longer time exposed to the object to make up for it; but the increased precision of all the foci may chance to make up for that loss of light.

This leads to a comparison of the different methods which are employed to obtain corrections. Varying the aperture of a lens, in proportion to its focus, is one mode of adapting a lens to different purposes. A single lens of small aperture, as *a*, fig. 27, may be so thin that the fault, fig. 5, is reduced almost to nothing, but if this small lens is made achromatic, it will of necessity be increased in thickness, and therefore have some of that fault. Very small apertures will give their foci *b b b*, so thin, or under so small an angle, as not to require very accurate adjustment; therefore, when the central foci are in correct adjustment, the rays of the marginal foci can extend beyond their correct point, and impinge on the flat surface with so little opening or spreading as scarcely to be noticed; and this fault can be still farther lessened by adjusting the flat surface midway between the long and short foci; this, therefore, offers the cheapest mode of reconciling a curved image to a flat surface, and may be used for all stationary objects where time can be allowed to effect the photogenic impression, and also when the image is to be obtained as near as possible to the full size of the object; likewise for obtaining very wide angles of view, as the oblique pencils are less damaged with a small aperture than with a large one. But take the larger aperture *d d*, and the wide angle will make the sharp points or foci at which the rays cross very precise; therefore a very little difference in their distance from the flat surface will make much difference in their spreading, and consequent indistinctness, as may be seen where the plane *b* cuts the foci short of their points *c c*. On this account, when large apertures are used, the central and marginal parts of a picture cannot be adjusted to equal distinctness at the same time on a flat surface, unless we apply a correcting lens. But for Photogenic purposes, the largest possible aperture is urgently desired, because the superior quantity of light transmitted by them, so very much quickens the process. Accordingly, the largest apertures are used for all moveable objects and transient effects, and Photographers are contenting themselves with pictures so much reduced as scarcely to be of use, for the sake of the flatness of the image thereby obtained, as was shown by fig. 18, and because the marginal indistinctness is not so visible to the eye in small pictures; although it has its full effect in obliterating or burring away the smaller markings.

But as reducing the picture much below the size of the originals is the only means by which the images of far and near objects can be projected together on the same plane, with nearly equal distinctness, we ought to improve those pictures to the utmost by using lens of much larger focus, and of course with proportionally large apertures, to effect the same reduction, and thereby render the perspective so gentle as not to suggest any distortion on that account, and also other faults are thereby reduced as the square of the increased focal length. The greatest improver of the oblique or lateral pencils is Ross's double achromatic lens, and therefore it is worthy of the greater expense, in providing two lenses of apertures twice as big as the working aperture for each pencil; yet this needs the correcting lens to flatten the curved picture or image.

I have now endeavoured to lay open every particular concerning lenses, that are used for cameras, and have given all the reasons I can to urge the use of lenses of long focus, whilst photographers have been endeavouring to obtain shorter foci to quicken the process; not thinking how much they are increasing the errors, and reducing the size of pictures; and not considering that shortening the foci was only beneficial as it enlarged the apertures. If they used lenses of long focus with apertures large in proportion, they would obtain the same quickness with much less distortion of the images. But lenses of short focus and small pictures cost less, and can be used in smaller premises, and more contracted places; all which, by reducing the art to a toy, enable persons to begin with less expense: they, therefore, become the playthings of a greater number of persons. But for seriously valuable work, as when the best statues and living figures are to be given with no more than the requisite degree of perspective, and free from distortion, and on so large a scale as to be useful in the arts; lenses of very large aperture and of long foci must be used; more particularly when public buildings and shipping with all the details of their rigging, are to be given of a size to be of any use to painters of those subjects; for none but lenses of long foci will give them of sufficient dimensions. There is no portion of landscape that painters are so deficient in as the surface of mountains and rocks; which is partly caused by the many difficulties that attend an artist while drawing in the open air, and in places where many of the requisite conveniences cannot be had. Very great aid will be given to artists when large views of the most expressive and characteristic mountains, rocks, and broken ground are obtained for them. To give images of all these objects of sufficient size, lenses of very long foci are required. Here is a large and new field opened for artists, and even traders in works of art. But against these improvements has been argued the great difficulty of obtaining glass good enough for very large lenses; but the fiscal regulations of the trade, which interfered so much with efforts for its optical improvement, are now happily removed, so that great improvements in this department may be anticipated.

APPLICATION OF A LENS.

For photogenic purposes, the person or other objects are placed in the best light that can be obtained, generally facing the south; and means are provided to keep them quite still during the operation. The lens *a*, fig. 28, is usually mounted in a tube, with a rack on it, by which it is adjusted to and fro in the outer tube *d*, on which its pinion is affixed; this outer tube *d* is fitted to the end of the box *e e*; made as dark as possible in the inside; stops at *e e e* help that darkness. The correcting lens *t* is to be fitted to the other end; and a frame just outside of it to hold the prepared plates or other surface. The camera, so prepared, is placed on any suitable steady support, with means for raising or lowering it, in order to choose the place of the horizon. The objects being in the direction *c*, the lens is directed towards them, and a plate of ground glass is first put at *b b* to receive the image and enable it to be adjusted to correct vision. When all is ready, the ground glass is removed, and the prepared plate put in; the usual process is then followed to complete the picture. It is well for this end of the camera to be in as dark a place as the operator can work in. On looking at or through the ground glass the picture is of course seen upside-down, but quite right in other respects; but when the opaque surface is put there, we look at the other side of it and see the picture as a reflected one: the right sides of all objects are therefore placed on the left; for some things this is of no importance, but for views and certain other objects, this must be corrected by receiving the image from a truly flat speculum, placed before the object glass *a*, at an angle of 45°. In the process called Calotype this fault is corrected by the second part of the operation.

There are two methods of taking the second impression. In one, the first impression is placed before the lens, by which its image is projected on to the second prepared surface, and by which the second picture is set right. By this method we have the liberty to make the second picture either larger or smaller than the first, but the lens adds a second portion of the error, fig. 5, to it. The other method is to place the face of the first picture close to the second, and letting the light pass through the first to the second. This of course sets the picture right with no additional error. In this way it is of consequence that the first paper be as uniform in its texture as possible, as all inequality in its transparency is liable to be shown in the second picture.

A CONCAVE REFLECTOR

Affords another mode of obtaining Photographic portraits; invented by Mr. Walcott, optician, of New York. It is a concave mirror of very large aperture, by which so much light is collected at the focus free from all separation of the rays, that it much quickens the operation. With this camera, the plate is put between the object and the mirror to receive the image; it therefore must be small, because its size obstructs so much of the light from the best part of the reflector. This circumstance limits its otherwise excellent performance. In fig. 29, *j j*, is the mirror; pencils of light *c c*, come from the objects to it, and are reflected back to the focus *b*, where they form the image. A thin frame is supported at that place by means that will obstruct the least light, and admit of adjustment; it holds the plate during the operation. In this camera the picture, being a reflection from the reflector, is given the right way, which is an advantage over the lens camera.

THE TRANSPARENT CAMERA

As usually made for drawing, has the parts arranged like fig. 30, and has either one or two lenses at *a*, a looking glass at *g*, and a plate of glass *h*, the upper surface of which is ground to enable it to receive pencil marks, and also to disperse the light about, and thereby render all parts of the picture visible.

If the Camera were made with only the achromatic lens *a*, and the correcting lens *t*, like fig. 28, it would be the most luminous of all, and the picture would be shown correct, only the images would be upside-down; but the artist, in order to avoid the trouble of acquiring the habit of tracing images in the inverted position, requires a modification of the instrument, which either renders it extremely expensive, or in reducing the expense of the camera greatly damages its performance by the introduction of a silvered looking-glass at *g*, as fig. 30, such glasses being very rarely flat enough for such purposes, and also having a double surface.

Thus for the sake of an erect image we add much to the faults by having it shown with the right side for the left, and the principal image burred by a fainter one a little on one side of it.

Fig. 31 shews the general arrangement of such a camera with the addition of a correcting lens: suppose an achromatic lens placed at *a*, (instead of the two here shewn), the rays from the object come in at *c*, and passing through the lens to a truly flat mirror *g*, will be reflected up to the correcting lens *t*; the image being formed at the upper surface *b*, may be traced on any very transparent paper laid there, and when this latter is placed upside-down on white paper the picture will appear the right way. This camera exceeds all others; for in addition to its brightness, its equal light all over the field, and its truth of form, it has a power which others have not; namely, that we can trace images nearly as large as life, for the surface being transparent, and the rays that form the image continuing their onward course to the eye, we can see the whole picture distinct; although some portions may be formed above the drawing surface, and some below it, but on account of the nearness of all the parts the eye easily refers them to the surface whilst tracing. The lid *l*, which shuts that part of the instrument, when raised as here shewn, will, with its two side cheeks *m*, sufficiently screen the surrounding light.*

The transparent camera will be much more expensive than the opaque one, if made worthy the present advanced state of optics. The mirror *g* is very large, and ought to be a truly plane speculum; and the hollow lens *t* is large, for the quantity of correction it affords to oblique pencils, and the complete flatness it produces all over the field enables us to use a much larger area, the whole surface being equally distinct. A smaller mirror, however, may serve the purpose, if the camera is formed like fig. 32, where the mirror is placed as close as possible to the object lens.

* The merit of having first applied a lens in the place of *t*, to render the picture equally luminous is due to a Mr. Storer. Many years before achromatic lenses were much in use, he seems to have discovered this effect, which made him apply earnestly to improve the Transparent Camera. He used two or three large double convex lenses for his object glass, and these lessening each others errors, enabled him to have larger apertures, and so obtain more light. They were placed as *a a*, fig. 31, in the separate slides *c i*, within a longer slide *j j*, and that in the box *k*. He placed a common looking-glass at *g*, and in the place of *t* a double, or rather equally convex lens; and over that a plate of glass *h h*, ground on the upper surface to receive pencil marks: the grinding has no other use, for it lessens the brightness of the picture. Thus built up, the picture shone equally before him, with a larger portion adjusted to the ground surface, for he had half cured the curvature and part of the distortion, but probably without being aware of this advantage, for it does not appear that he thought of the figure of his improving lens, otherwise he would have used its upper surface, and saved one layer of glass. Success thus far increased his ardour to get such instruments manufactured, but the obstacles in his way were more than enough for ordinary means. One of the instruments I examined, and found that the glass was exceedingly bad; the lenses were so veiny as to damage the image. The looking-glass, in addition to the evil of double surfaces, was the worst I ever saw; it was polished with a motion all one way, which gave it a surface like wire-marked paper; then the lens which rendered the whole picture luminous was very veiny, and the plate of ground glass over it, altogether produced such a mass of confusion as greatly to disappoint me in seeing so bright an image so ill defined, and thus from defects in the materials and in the workmanship Storer appears to have been baffled; and when he sought aid from others to overcome the difficulties, instead of some gratitude for what he had done, he was looked upon as a schemer seeking to profit by others money.

OPAQUE CAMERAS

Are the simplest in construction, having only a flat speculum and one lens, which should be achromatic; but for short foci Mr. A. Ross's double achromatic lenses are much the best, because they correct the lateral pencils, and so give all the images distinct. To this camera we cannot apply a correcting lens, and are therefore obliged to submit to the distortion and to a curved picture. When we receive the picture on a flat surface, as *b b*, fig. 33, we may adjust the middle *c* of the image to touch it, and having traced that portion raise the board till the parts *d d* coincide with *e e*, and trace those portions. Here will be much distortion, for by fig. 15 it was shewn that the thickness of the lens had laid such rays as *a e b* a little too much inwards, causing some distortion, like fig. 5. Hence if the rays *a e e* extended even to *b b*, there would be that small defect; but now they are received at *d d*, causing a much larger amount of that distortion. Therefore, with this camera, we should never use a flat board but one cylindrically hollowed to fit the curve *e c e*. We thus have the advantage, that the right and left side will be in adjustment with the middle, aud when the paper is again laid flat the sides *e e* will extend to half way between *d* and *b*, thus half curing the distortion: but there will be no cure for the top and bottom of the picture. But seeing that half the diameter of the area will have four times less distortion we should only trace about the middle portion, and successively bring the other parts to the centre to trace them, whereby we shall avoid much of the distortion. Fig. 34 represents the manner in which I have fitted up such cameras; the box *w* contains an oval flat speculum *g*. The light from objects enters with the arrow *c c*, and is reflected downwards through an achromatic lens *a* and forms the image at *b* on the board *h h*. Here the reflection at *g* is corrected by the second reflection from the paper at *b*, so the image is shown the right way. The arrow shows that the picture is seen erect when we turn our back to the object. The four bars *s s* fit into sockets at top, and are jointed to the board *h* by hinges, with loose pins like fig. 35; that the whole may take to pieces for portability. The space between the bars *s s* is made effectually dark by a soft black leather cover, fig. 36; the button holes *x x* fit studs *x x*, fig. 34; and a string is run round the bottom edge, which serves to draw the cover tight round the margin of the board *h*, the strap 1 placed over the head keeps the opening *y* close to the eyes, and the hand is put through the slit 2, to trace the image.

In this instrument the image is projected against white paper which disperses the light in all directions; it is only some of this dispersed light which enters the eye, consequently these images are never seen as bright as with the transparent camera, and therefore it requires the most careful darkening to see them. The eye knowing nothing of any image but what is reflected from the paper, any portion that is formed either above or below the paper, appears merely as a mixed mass of colour; giving no intelligence of what it is. Therefore this camera requires means of accurately adjusting the board to each part of the image while tracing it.

CAMERA LUCIDA.

Invented by Dr. Wollaston is the next optical instrument for drawing. It is the smallest instrument in proportion to its usefulness that has been brought forward, and therefore great numbers of them have been made: and yet they are very rarely provided with the means that will give them the utmost efficiency, nor are the purchasers instructed how to obtain it. The following description may remove that defect. This instrument consists of two reflecting surfaces joined together at an angle of 135°. There are different modes in which it can be constructed, but the one generally adopted is a glass prism, scarcely an inch in length, and about half an inch thick.

This prism possesses two capital advantages—first, its great portability, and secondly, the great perfection of the reflecting surfaces; for these, being internal, absolutely reflect the whole of the light with no loss but what imperfect polishing will occasion. Fig. 37 is a perspective view of one. The upper surface and the front face are at right angles to each other. Rays of light from the objects enter the face with the usual loss of some light, and impinge on the first and lowest sloping surface *a*, from which they are totally reflected to the second sloping surface *b*, which again totally reflects them upwards to pass through the upper surface, with the usual and unavoidable loss of some light. The entrance and exit of this light is always at the same angle; so that there is no prismatic division of the light. The eye at *c*, receiving the light, sees the objects downwards in the direction *d*, either on or through the table, just as far off as when looking direct at them, the prism having only made the object appear to be in the direction of the table, where the paper can be put to trace it. The surfaces that reflect the light are internal surfaces; consequently they are mathematical planes, having no thickness; on which account this mode of construction is the best, because the action of the eye is to be divided—the upper half looking into the prism, whilst the lower half looks at the paper, there is no thickness between, and thus the pencil and object may be seen together.

When tracing an object or picture of the same size as the original there is no difficulty. If the paper is eighteen inches below the prism, the object will be placed the same distance in front, so both pencil and object will be seen together by the same adjustment of the eye. But when a reduced copy is to be made, say to one quarter, then the object will be four times further off than the pencil: the pencil and object cannot, therefore, be seen together by one adjustment of the eye; and if the object be a mile off there will be that enormous difference between its distance and the pencils, yet the whole of this difference can be removed by a suitable lens. First, fix the prism above the paper at the height most agreeable for general use; call that distance one: then take a lens, whose focus is two, and place it at *e*, close under the prism; it will make the paper and pencil appear twice as far off; and thus an object may be reduced to half size with perfect distinctness, for the pencil will appear to touch the object. A lens of one and a half focus will place the pencil three times as far for reducing to one-third. A lens one and a quarter will suit five times the distance; one and one-eighth nine times the distance; one and one-sixteenth agrees with seventeen times the distance, and suits that degree of reduction; and a lens, whose focus is one, will render the pencil distinct at the same time with the extreme distance, then, by a little altering of the height of the prism and lens, the pencil may be rendered coincident with the intermediate distances.

ERRORS OF THE PRISM AND LENS.

The light entering the front of the prism perpendicular to its surface, and in like manner going out of the top surface, amounts to the same as going through a thick piece of parallel glass. But thick glass magnifies in an increasing ratio from the centre. Let *aa bb*, fig. 38, represent a portion of thick glass; any rays oblique to the centre *c*, as *d e* and *f*, coming from different objects will be bent upwards at the surface *b*, to pass through the glass, and on emerging they will be bent back by the surface *a*, parallel to their former direction, and enter the eye at *g*; the eye looking along these rays, sees the object over or above the rays *d f*; and under a larger angle than if rays had gone direct from the objects to the eye, and the objects appear to be lifted up so much nearer to the eye.

Many people have noticed that a clear river appears to be shallower than it really is, The same figure, 38, will show how that occurs. Let the line *bb* represent the bottom of a river, *a a* its surface. The eye at *g* receives cones of light from the various points *o* 1 2 3 4 5 6 on the bottom *b b*, and the cone *g* 6, is nearly three times as long as *g o*; therefore, its angle is about three times less. Now, the naked eye, adjusting itself to these various angles, becomes sensible of their respective distances; but the eye looking at the point 1 will see it in the direction of the dotted line; it will, therefore, be raised and moved aside to 1'; in like manner the other points 2 3 4 5 6, will be still more moved aside and raised to the dotted curve *o'* 1' 2' 3' 4' 5' 6', where the eye imagines the bottom to be. All farther distances of the bottom beyond 6 will be very little more raised than 6 is; but they will gradually become darker, so that the eye will lose sight of it, and see reflections from the surface *a* instead. I have shown that the line *b b* is much magnified by being seen through the medium *a b*: but were the object a mile off, it would be only this given quantity larger, therefore, it will be too little to be noticed for distant objects. I have shown above that for tracing distant objects, the hand must be seen through a lens to make its apparent place coincide with those of the objects; and this lens, as was shown in fig. 7, will magnify the lateral portions of the paper more than the central ones; therefore, when those parts are drawn on, and afterwards looked at without the lens, they will be that quantity too small compared to the central ones. This fault being greater than that of the prism, and contrary to it, more than counterbalances it, leaving, however, instead the greater portion of its own fault. But if we attempt to copy a picture larger than the original, it must be placed as much nearer to the prism than the paper, as will give the required size. Then the lens must be placed before the prism fig. 37, so as to make the picture appear as far off as the hand is, and thus enable both to be distinctly seen by one adjustment of the eye. In this case both the prism and lens conspire to produce the same distortion; and which, in many cases, amounts to so large a quantity as to be quite unbearable. In all cases of distortion the errors lessen as the square of the area, so that for objects about the centre of view the distortion is so small as not to be of consequence. On this account the prism never distorts high and low objects in any sensible degree, because we only see a short portion of the height at one time, and have to turn the prism up or down to see higher or lower portions; so that we look nearly direct through it for all those parts, while the right and left objects are seen by looking obliquely through the prism. The faults of thickness in the prism are only visible for near objects, or wide angles of view, and those may be removed by placing a piece of suitably thick glass under the prism to affect the hand as much as the prism affects the object, so fitted; the performance of the prism may be correct, while we do not combine a lens with it. The thickness of the glass that will match the prism must be equal to the passage of the light through the prism to make it fit for drawing an object of the same size as the original; half that thickness will match when drawing half the size, and one quarter for reducing to one quarter, and so on. But as images much reduced need a lens to cause the pencil to appear at the same distance as the object, that lens will do more than correct the prism. With the prism the whole of a tall object is not seen at once, but, owing to the two reflecting surfaces, the prism may be directed to the highest or the lowest part, without altering the place of the image: thus every part of the very tallest object may be drawn.

A SINGLE REFLECTOR

Forms a very useful instrument for showing objects or pictures the reverse way, by which they may be etched on copper or drawn on stone for printing the right way. Fig. 39 represents the instrument fitted for copying drawings: *aa*, a perpendicular board against which the drawing is placed upside down; *b*, a flat speculum: its upper edge *i* is ground nearly to a knife edge; it is fixed at an angle of 45° and supported by a side arm *c*, and block *d*, so as to hold the speculum perfectly midway and midangle between the board *a*, and drawing surface *e*; *f* is the drawing to be copied, fixed upside down against *a*. The eye, whilst looking into the speculum, will apparently see the drawing erect and perfectly correct on the surface *e*; and it may be easily traced by letting part of the eye look over the edge of the speculum and down on the paper to see the pencil whilst drawing. When a drawing is to be reduced, slide the board *d* the right distance back, and put a suitable lens (as formerly explained) in the ring *g*, then the pencil will appear to coincide with the image, and it may be traced

TO DRAW FROM NATURE

the reverse way requires the stone or other drawing surface to be placed upright like *h*, fig. 40, and to have the speculum *b* and lens *g* stand before it; the speculum at an angle of 45° to receive the light from objects, either on the left, as shown by the arrow; or on the right, as may be convenient. A ridge, *j*, may be fixed on the foot board *k k*, on which a groove in the foot *d* can slide, to keep the speculum always at the proper angle, and yet allow it to be placed nearer to or farther from the drawing surface *h*. In this instrument it is, for several reasons, of consequence to place the speculum *b*, correctly at an angle of 45° to the drawing surface; in which case it is best for that surface to be kept quite horizontal, or quite vertical whilst drawing on it.

There is another instrument invented by Mr. Lorimier, which, though not strictly optical, bears so much relation to such instruments as to claim and deserve a place among them. It is a new mode of dividing the eye, and one that any person can use. Fig. 41, *a a*, is a frame fixed vertically, as here shown by a very simple and effective contrivance. It contains a plate of glass *b*, *c* is a sight-hole adjustable to and fro, and higher and lower, by which it may be placed at a convenient distance from the plane, and at the height most suitable for the horizon. On the glass *b* is placed a sheet of paper, perforated all over with very fine holes, so close as to remove nearly one quarter of the paper. When this is placed before any object, or view, with the eye at the sight-hole, those objects can be seen through the paper, and may be traced on it in perfectly true perspective, there being no optical errors introduced. This mode of mixing, as it were, the paper and the objects, prevents the eye feeling any inconvenience from the different distances of the two. I, as an artist, think this is one of the best helps to a teacher of perspective that has been brought forward; it so easily demonstrates any, or all the truths of perspective to the pupils sight, as they can so easily trace the object, and then apply the rules to prove the perfect agreement of the two.

The small instruments, I have above described, cannot set the artist at liberty; they confine him to very small pictures, if the objects are sufficiently distant to be agreeable in their perspective, or else he must endure very violent perspective, which unfits them for pictures of greater perspective distance, and he cannot sketch as large as life. The camera obscura, though unlimited in theory, is very so in practice, from the great size required to obtain large pictures; and the difficulty and expense of rendering them steady in the wind, and of moving them from place to place. All these obstacles are removed, and the artist set quite at liberty by the

GRAPHIC TELESCOPE,

with which the most distant views, or the nearest objects, may be traced of any required size. It, therefore, gives an unlimited choice in the size of the sketches, for they may not only be made of any size an artist can wish, but also from objects at any distance he may like. He can, therefore, choose the exact degree of perspective that will suit his purpose.

In order to make this instrument understood, its difference from the previously known and excellent instrument, the camera obscura should be shown, and then its mode of action; thirdly, its construction; and, fourthly, the various purposes to which it may be applied.

The previous description has shown that the opaque camera obscura is formed with a plain mirror and a lens, which projects a picture on paper; but to render that picture visible, the whole space from the lens to the paper requires to be inclosed in a dark chamber, so as totally to exclude all other light; hence its name. Images of any size, and of sufficient brilliancy, may be formed by that instrument, if we use a large plane metallic speculum, and lenses of sufficiently long focus, and so well constructed as to bear, and have, the largest possible aperture. The distance of the lens from its focus being the perspective distance of the picture which it produces, or, in other words, it is the distance of the station-point from which that picture should be viewed; because it then appears exactly of the same size as the original objects.

A camera obscura may be constructed with a variety of lenses to give images of all the most useful sizes; yet the expense and trouble of moving it from place to place, and its high and broad surface enabling the wind to interfere with its required steadiness, are objections to its general adoption.

The image given by a telescope is subject only to few of these objections. The size of the image does not depend on the focal distance of the object-glass, but on the proportion between its focal distance and that of the eye-piece; and the brightness of that image depends, within certain limits, on the diameter of the object-glass. Therefore, a small telescope will give an image as big as a large camera obscura; but it will not project that image on paper, and, as we usually look into the telescope to see the image within the tube, it cannot be transferred to paper by tracing. In my graphic telescope, I have contrived to place the image apparently outside of the tube; and, although not actually projected on any surface, yet the observer receives the rays from the telescope into his eye, in such a manner that they may be made to appear to come from a sheet of paper suitably placed for the purpose; therefore, this image may be traced on the paper. The size of the image may be varied very considerably, without altering the size of the apparatus: sketches, therefore, on a very large or very small scale, may be made by the same instrument; and as it never requires any additional height, or any shade to exclude daylight from the image, it offers no broad surface to be affected by the wind, and thus be rendered unsteady.

The image which we are enabled to trace with this instrument is a telescopic one; and I will now show how that image is produced:—Fig. 42, plate 7 is a diagram of one of the smallest graphic telescopes, half the real size, containing all the optical portion freed from the surrounding tubes. Let the arrow *a b* represent an object to be drawn; in this instance it is a near one, the instrument being used as a microscope: *c* a flat speculum placed at an angle of 45° with the axis of the telescope; it receives the various pencils of rays which diverge from every point of the object (to avoid confusion, only the middle and two extreme ones are shown), and reflects them to the double convex object-glass *d*: this is sometimes made with two such lenses; but the larger instruments have achromatic object-glasses; in all cases, the thinner the object-glass is the better: the object-glass refracts the various rays about its focus, so as to form the curved image *a' b'*: here these rays will cross and diverge, and are to pass through the eye-lens *e*, which will render them so nearly parallel as to give distinct vision of the image, the eye-glass being placed so that its focus just meets that of the object-glass. But though the central pencils of rays would proceed to the eye-lens *e*, it will be seen that the outer pencils would pass on in the direction *f f* beyond the diameter of the lens *e*, and be lost: to prevent this, another lens, or two equivalent ones *g g*, must be placed near the image *a' b'*, where the rays cross. A lens so placed does not affect the crossing of the rays, but it deflects each pencil in mass towards the axis, from the course *f f* into the course *h h*, where they will arrive at the eye-lens *e*, and by it be refracted at a still quicker rate towards the axis, and rendered nearly parallel. These pencils are all of the same size, and meet together in the axis, where, if the eye is placed, it can receive them all, and will then see the whole area of the lens filled with the image: this area is called the field of view; and because the lens *g* greatly increases the diameter of that area, it is called the field-glass. The pencils all meeting together, a cap with an eye-hole of the size of one pencil is usually put there for other purposes, that being large enough for them all to pass through to the eye.

It will be seen that the image *a' b'*, fig. 42-43, is convex about the object-glass as a centre, whilst the eye-glass evidently needs the image to be concave, as *d j f*, fig. 43 and 44, to show every part distinct at the same time. This great defect is quite cured by the field-lens *g*, fig. 44, which is so formed as to reverse the curve *d j f*, and convert it into the opposite and exact curve of the image *a c b*. The middle of this field-lens is much nearer to the eye-lens *e* than its circumference is; it therefore acts much more powerfully on the middle pencils of the eye-lens to shorten them, so that instead of their extending to *j*, they only reach to *c*, whilst the pencils that approach the margin gradually suffer less and less of this action, and more and more deflection, so that whilst they are ranged in the required curve *a c b*, they are also being deflected in the exact quantity to meet and correspond with the various rays *i i*, and *k k*, which come from the object-glass; consequently all those rays, as *i i*, are directed along *h h*, and then *l l*, into the eye at *m*, and the whole image becomes equally visible and distinct under the enlarged angle *l m l*. In addition to these two actions—namely, shortening the central foci and directing all towards the object-glass, the central foci have their place changed more in proportion than the outer ones, for they now meet the inner pencils *i i i i*, instead of the dotted ones *k k*, this smaller image is, therefore, magnified to appear as big as *k k*, whilst there is scarcely any such action as this at the margin. This gradual increase of magnifying power towards the centre, which by itself would be a fault, thus induced becomes an exact balance to the counter fault, naturally belonging to the eye-lens (as was shown by fig. 7), and thus all distortion is removed: straight lines are shown straight in all parts of the field, the whole becoming flat and equally distinct and visible. The curvature of the field-glass that will render the largest field distinct all over is a meniscus, the concave side of which has a radius half its distance from the object-glass, and two of these instead of one performs best, because of the well-known law, that the error by figure is four times less with two lenses than with one. If the focal distance of the eye-lens is two, its aperture should be one, and that of the field-lens will be three, and its aperture two; but when two lenses are used, their focal distance may, together, be a little less than three.

The various pencils of light, after passing through the eye-glass *e*, fig. 42, are to be directed upwards into the eye; therefore, a second flat speculum *i* is placed before the eye-glass at an angle of 45°, so as to receive all the pencils just as they meet together, and reflect them upwards into the eye. As the eye is to be put where all the pencils meet, there must be no portions of speculum higher than that little circle of congress; and as a portion of the eye is to be allowed to look over the edge of the speculum, its upper edge is ground as thin as can be done with safety. This completes the optical part of the instrument. If we now look downwards into the eye-speculum, and leave a portion of the eye to look over its edge towards the arrow *a'' b''*, where the drawing paper is placed, we shall receive the rays from the telescope in exactly the same direction and divergence as those that enter the eye from the paper, and both image and paper will be seen together distinctly, and will allow that image to be correctly traced on the paper. When drawing with this instrument, the eye can be so placed as to remove any portion of the image from the lower part of the paper: the pencil is best seen in this lower margin, where the image is beginning to disappear. For the sake of room in the engraving, the image *a*'' *b*'' is placed too near: in proportion to this diagram, that image would be nine inches below the eye-piece, and five times as large as it is drawn, because the extreme parts *a*'' *b*'' will always be seen in the direction *i a*'' and *i b*''.

Directions for Using the Instrument.

A telescopic image has an advantage over others, in that it can be placed at any required distance from the eye, and thereby be rendered distinct to any sight: and this is an important feature in the graphic telescope; for it allows us to place the paper at the most eligible distance from the eye, and then, by adjusting the telescope, to bring the image to exactly the same distance, when the pencil, or crayon, and the image will both be seen together equally distinct; and then both eyes may be open to see the pencil, though one only sees the image. When the eye-piece is drawn away from the object-glass to the utmost extent compatible with seeing the image of a given object distinctly, the rays from the eye-glass which enter the eye are parallel, and the image appears distant, so we cannot place the paper far enough to see both together; but by pushing in the eye-piece a little, the rays will diverge a little, as though they came from a nearer object; and if we push in the eye-glass as much as we possibly can, consistent with distinct vision, the rays will diverge as from the very nearest object that can be seen distinctly, and the paper would require to be placed as close to the eye as it could possibly be seen distinct. It is a very small distance that we have to move the eye-piece to produce the extreme effects; therefore, when good vision is obtained, it is easy to adjust the instrument so that the rays shall diverge exactly as much as those which come from the paper. The dotted rays from the arrow *a'' b''* shew the divergence of those that proceed from the eye-glass against the speculum and into the eye, and thus make the image appear to be at that exact distance. When we have to make an extremely small copy from a large picture, we need not effect the whole reduction by giving the required distance to the picture, for ordinary rooms do not allow that distance; but I place the picture as far as I can, and do the rest by using spectacles, the focus of which is so short, as to let me see the paper when placed so near as to reduce the image to the required size. This diagram represents the instrument in use as a microscope; for the object *a b* is near, and the image *a'' b''* is larger than it; but the object-speculum *c* is made to revolve on the axis of the telescope, so, if it is turned a quarter round, it will receive rays horizontally from objects at any distance; then the parallel rays *j j k k* will represent the pencils of light which proceed from a distant view, and these will include that portion of it which will just fill the field of view, and be represented by the arrow *a'' b''*.

Having now explained the principle on which the instrument acts, I will describe its mechanical construction, by which it is adapted to the various purposes of drawing. Fig. 45 represents a small graphic telescope, such as will include the diagram fig. 42, these figures being half the real size; *l m* the tube, containing two inner ones to draw out: at *m* is a ring-seat for the eye-piece; it is only seen by dotted lines: at the end of the inner tube is a neck *n*, shown separate in fig. 46; it is screwed within to receive the cell *o*, which contains the object-glass, and it is screwed on the outside to receive the short tube *p*, which contains the object-speculum *c*. Fig. 47 shews this in section: the speculum is lodged in an inner tube *q*: this tube is only confined in the tube *p* by the screw *r*, fig. 45, which also serves as a nib to turn the inner tube round, and so shut up the speculum: *s* is the aperture for the rays to enter: *t* is the eye-piece: one portion is cylindrical, to slide into the tube, and stop against the seat *m*: the outer end *v* is also made cylindrical, and then the top *v* is filed away to admit the eye, and the bottom *u* is filed away to let the eye look through; two grooves are made within the neck, as shewn at *v v* in the front view, fig. 48; these receive the slide *w*, a top and side view of which is shewn in figs, 49 and 50: on this slide, the eye-speculum *i* is cemented with black sealing-wax. Fig. 51 shows the upper edge of the speculum *i*. Fig. 52 is a section of the eye-piece, to shew the three lenses, and how the whole is put together: *x* is a cap that slides on the neck *v* to shut up the eye-end: *y* is a broad cap screwed into the other end when not in use. This eye-piece is made to enter the telescope either end foremost; therefore, when packed up, it lodges in the tube *l m*, fig. 45, in the position shewn in fig. 52, and the cap *y* serves to pull it out by. I have now described a small graphic telescope, the powers of which is varied by changing the object-glass; the shortest object-glass is four inches focus, the next six inches, and the third eight inches focus; these, with this eye-piece, magnify three, four and a half, and six times; for greater powers, longer tubes are used, with ten-inch and twenty-one-inch object-glasses, and a third size made to hold a three-foot object-glass: with these larger ones the size of the eye-pieces are also varied, the smallest having an eye-lens of one-inch focus, and the largest being made with an eye-lens of two and a half inches focus.

Two sorts of stands are provided for using these telescopes on. Figs. 53 and 54 are two views of a mahogany stand, by which the telescope may be used on any steady table: it is made to fold up by being jointed at top with a common hinge, and hollowed at each side to receive the telescope; then, to increase the grip round the telescope without using thicker wood, two stubs of wood 1 1 are fixed in on each side, and these have centre-bit holes opposite them, to let the stand shut close when out of use; 2 2 is a wire fitted in with a pin at each end; this fastens the telescope, and makes the whole stiff together (this wire is shown separate just below); one of the pins takes out to let this wire fall into the groove 3. A pin 4 fixes the leg 5 in its right place; in the latter there is a hole 6 by which the same pin 4 fixes it when shut up, the leg being made to move on the screw 7. This stand is constructed to leave the space on the table under the eye-piece quite clear, and so make room for paper to be laid there. Although this stand is a good one, it confines the use of the telescope to places where a steady table can be had, and with that it cannot easily be used on uneven ground; these and other difficulties are most effectually overcome by the construction of the table and stand fig. 55, and this I find by long experience completely answers its intended purpose! it may be used on the most uneven ground, is quite steady even in a windy day, is very light, and folds up within three inches of thickness, and, therefore, is very portable. 8 8 is the table, about nineteen inches square; it has three legs, one in front is made of the four square sticks 9 9 9 9, which spread to the four corners of the table, and one at each side is made of two sticks 10 10 and 11 11. The four sticks of the front leg are jointed together at bottom by four hinges, as shewn in fig. 56, and the mitres carefully made to be close when the sticks are spread out; their upper ends are made fast to the table by four hinges; these, not having to move as hinges, but to act as convenient connexions, are placed in any convenient position; the side-legs are jointed at bottom by one hinge each, also with a close mitre, and at top they are jointed to the table by two hinges each, as close as possible to the four sticks 9 9 9 9. These side-legs being moveable, to suit uneven ground, their hinges are carefully placed in line with each other; when these side-legs are spread out wide enough to make the table stand level, or at any convenient slope, they are confined from going further by strings 12 12, which have loops to fit on the point of the legs; they then cross under the table to its opposite sides, where, by loops at their upper ends, they catch on to one of the screws or knobs sticking out for that purpose. Fig. 57 is the under side of the table, to shew the place of the eight hinges: these have their pins driven out, and steel pins with ring-ends are fitted to them; thus the legs are readily attached to or removed from the table, and these legs fold up in eight close sticks. The two legs 13 13 which hold the telescope are hinged together at top, as shown in figs. 53 and 54 of the other stand, (fig. 59 is a front view of this part of fig. 55 separate); but here two more legs 14 14 are added; these four are hinged to the table with moveable pins, as shown in fig. 58. They hold a short telescope, like fig. 53 and 54, sufficiently firm; but when the telescope is a long one, it requires two more sticks 15 15 to be added; these latter are joined by a sliding nut and screw 16, and are each attached at bottom by one screw to the hinge-flap, which is removeable by pins like the others; a string 17 holds them up against the telescope. This upper stand is placed so that the edge of the eye-speculum shall be over the middle of the table, and eighteen inches above it. To direct the telescope to the right or left, we may move table and all together, but in difficult ground this is liable to be inconvenient; for such cases the upper stand 13 14 15 should be attached to a separate board, and this made to turn on the table 8 by a central pin; then, if the table is stuck fast in the ground, it will be more completely steady, and a full range of view may be had without disturbing it, but when moved to take in a second or third portion, clamp the board and table together again, to make the whole quite firm and steady. The position of the two speculums, at an angle of 45° with the axis of the telescope, requires that the telescope should be parallel with the table, and whilst that is the case the table may be level, or put in any convenient slope. When drawing a view from nature, this parallelism must be observed if the horizon crosses the middle of the field of view; but, should the object-speculum be directed much above the horizon, to the top of a tower, for instance, the top being further from the telescope than the bottom, would be seen smaller, *i. e.* there would be perpendicular perspective: this is easily corrected; but before doing so, another property must be explained. By considering the diagram, fig. 42, it will be seen that if the paper was put nearer to the eye than the arrow *a*'' *b*'', that image would be exactly so much smaller, and on putting the paper further off, it would be so much larger. This enables us to make large or small sketches with the same instrument, by only altering the distance of the paper; but leaving that for the present, this property will at once shew the means of correcting any error; for, suppose the image of the top portion of a tower, which should extend from *b*'' to *a*'', is so deficient that it extends only to *s*, let the paper at *a*'' be lowered to *a*''', leaving *b*'' where it is, the eye will then look through *s*, and see that part of the image extended to *a*''', where it is restored to its proper dimensions. If the observer was on the top of a high building, and directed the object-speculum downwards, then the same sort of correction would be made at the part *b*'' instead of *a*''. The eye-piece, instead of screwing, is made only to slide into the tube, in order to allow it to be turned round to the right or left, and so assist to effect the same kind of correction when the view is much extended to the right or left. The cases where this correction is needed occur very seldom, and then the correction is inversely as the power; for, when the instrument magnifies three times, 1° of slope given to the paper will correct 3° of change in the telescope, and with power of six that 1° will correct 6° of change.

With the two stands now described, this correction is effected by using a drawing-board with four short feet, made by passing a screw through each corner; thus either end, or either side, may be lowered till the image is rendered correct.

Having now described the graphic telescope, with its different stands, I shall proceed to show that it is also a graphic microscope, as far as artists usually require, premising that whenever it gives an image larger than the object it is a microscope, and that, though a telescope magnifies most with an object-glass having a long focus, it is the reverse with the microscope; for that magnifies most with a short focus object-glass, and the further that is placed from the eye-piece the greater will be the power.

With a graphic microscope we may trace an image much larger than the stated magnifying power, for ten inches is the distance at which the magnified image is measured, and though we sometimes trace within that distance, yet we may draw at the distance of eighteen inches, which makes the image four-fifths larger.

I will show how the telescope may be used as a microscope:

The telescope, fig. 45, or 54, being suited to receive either a four or an eight-inch object-glass, put the shortest one in, and pull the tubes out the full length, which is rather more than double the focus, therefore it will require the object to be placed within eight inches distance from the object-glass, to enable it to give an image at the eye-piece. This image will bear exactly the same proportion to the object as their respective distances are from the object-glass; in this case it will be a little larger, and the eye-piece will magnify the image about six times; and if the paper on which the image is traced be more than ten inches distant from the eye-piece, it will be still larger, so that this combination will make a miniature of one inch appear as large as life. We may sometimes lay the object on the table or drawing-board, like *a b*, fig. 42, because then the same board will hold all together quite steady, and gradually raise it till its image is given large enough. If the object is placed vertically on either side of the object speculum, the instrument may be slid on the table to or from it till correct vision is obtained: even here, that all may be held together, it is preferable to clamp this side-support to the board. In this, as well as in a telescope, the image will be gradually lessened if we gradually increase the distance of the object; and gradually slide in the object-tube to regain distinct vision, so we can always choose the exact size that is most eligible. It is obvious that, by using object-glasses of shorter focus than those provided for the telescope, we may carry on the power till it equals any other microscope.

But in this form it is not so eligible to use an object-glass of shorter focus than three inches, on account of the great steadiness required; therefore, for high powers, this graphic eye-piece may be adapted to any good microscope that can be placed horizontal, but particularly to a microscope of my own construction, for which I was honoured by a gold medal from the Society of Arts, &c., in 1844, and of which a full description is given in their "Transactions," vol. 55.

Fig. 60 is a side elevation of this microscope, placed horizontally, for the purpose of using the graphic eye-piece, the object to be drawn is placed against the stage *a*, and held by finger springs *b*; *c*, a lever to move the stage laterally; *d*, the object-glass; *e*, the body which, for ordinary uses, receives the usual eye-piece—but here an adapter, *f*, is put in, to which the graphic eye-piece, *g*, is fitted, (this eye-piece being the same as that described with the graphic telescope) the rod *h* is slid out enough to receive the holder *i*, which supports the eye-piece; *j* and *k* are the quick and slow adjustments. The eye-speculum at *l* being placed at an angle of 45°, turns the pencils of rays from the image upwards to the eye as *m m*, which makes the image appear to be in the direction *n n*, and the vision of it can be adjusted to coincide with the paper at any required distance below the eye-piece, as at *o o*. The microscope is mounted on a stool, *p*, for two reasons, first, to elevate the eye-piece to eighteen inches above the table; secondly, to raise the whole instrument out of the way of a large piece of paper, in order that this latter may be freely moved about to bring different parts under the eye-piece; it also holds the lamp, or other conveniences, quite out of the way of the drawing. A brace *q*, opened like the letter A, supports and steadies the eye-end of the microscope. As the drawing will be larger, or smaller, according to its distance from the eye-piece, the paper may be raised up, or lowered, to obtain any intermediate sizes between those given by the different object-glasses. The microscopic images are to be traced precisely like the telescopic one, by part of the eye receiving the rays *m* from the speculum and the other part, looking over the upper edge of the speculum and down on the paper *o o*, to see the pencil.

I have now described the most efficient optical drawing instruments; it remains to make a comparison between them, in order to show their different capabilities :—

First, that excellent little instrument, the *camera lucida*, the *single reflector*, and *Lorimier's transparent planes*, do not magnify, consequently, the size of the sketches aré limited by the length of the arm; therefore, eighteen inches is about the greatest distance from the eye that we can conveniently draw with them, many persons preferring a less distance. Now, it must be a very small picture that requires the eye to be only eighteen inches from it, and if a larger picture is made from such sketches, the artist is obliged to supply from his knowledge the features that were too small to be more than hinted at in the sketch. And if we approach individual objects for the purpose of obtaining larger sketches of them, the perspective becomes too violent to be born; these are, therefore, totally unfit for use in large pictures; for in sketching objects to introduce, afterwards, in pictures, the safest fault is to have too little perspective, rather than too much.

The *single reflector* is only preferable to the camera lucida when the drawing is to be reversed, as it must be on the stone for printing the right way, or when the right and left side is of no consequence.

Lorimier's transparent planes necessarily show the objects quite correct, but the paper being perforated, we should only make sketches on it, to be copied, or transferred, to other paper or pictures for finishing.

These instruments are limited precisely as lenses of short focus are, distant objects being given too small, and very near ones being much too violent in their perspective.

The *camera obscura* has no such limits, whatever perspective distance we wish the pictures to have, take a lens of that focus, and all the objects will have the true perspective for such distance; therefore, with it we can have very large, or very small sketches of any required degree of perspective, and the image given by a camera obscura is the easiest of all to trace; but the camera must have a considerable variety of lenses to be generally useful, because it has no other means of varying the size of the sketches. Thus fitted, its weight becomes considerable, and the great bulk of its dark chamber renders it difficult to convey from place to place, as well as to keep it quite steady in windy weather. The opaque camera distorts the image. The transparent one with correcting lens, gives the image quite true in form, and very much brighter, and equally distinct all over. The transparent camera also having its length horizontal, is easier to support, and from its superior brightness enables views to be taken under circumstances that could not be done with the opaque one; but its expense and weight would be considerably greater, and its low horizon would often require both it and the draftsman to be elevated three or four feet to obtain a reasonable height for the horizon. Yet if these cameras, with a variety of powers, were so fitted as to make them quite steady, and furnished, occasionally, with a pair of wheels, or even placed in a four-wheeled waggon to facilitate their motion from place to place, they would become most desirable instruments, and would greatly facilitate the acquiring larger and more accurate drawings from nature, than are usually obtained without such aids.

But there are many obstacles in the way of using such aids, unless they are portable in the full sense of the word *i. e.* admitting of being taken over stiles, along footpaths, through forests, or over any broken ground, on mountain sides, &c., or be allowed in parks without the ceremony of asking leave; for if not, they become serious clogs to an artist, and prevent his choosing many of those very spots that he would be most desirous of drawing from. Again, many who have provided such aids, on attempting to use them, find they are not sufficiently steady, and they give up the hope of having any support that shall be both steady and portable. These are unpleasant drawbacks, but yet so large a portion of important work may be done by them, that it is a pity they are not much more in use among artists: these and similar obstacles almost prevent artists from habituating themselves to the use of such aids. Therefore, notwithstanding the greater ease of drawing with these instruments, they are giving place to the camera lucida, and the graphic telescope. The camera lucida is very portable, but it is limited to small work. The graphic telescope is portable, and very steady even in windy weather, and it is unlimited, and an artist can take it out with but small assistance, or even by himself, if he so chooses. I have shown the limits of the camera lucida, and if we assume its power to be *one*, the small telescope begins with a power of *two*, but is reducible in any degree towards one, by bringing the paper nearer towards the eye-piece; its next power is *three*, and it has another power of *four;* or, by changing the eye-piece, these powers may become *three*, *four and half*, and *six;* all variable, as above stated, by placing the paper nearer too, or farther from, the eye-piece. Another size ranges from five to twenty: the power of twenty will give sketches with a perspective distance of thirty feet, which, consequently, are of the exact size for a panorama of sixty feet diameter. These extra powers are but rarely wanted, from two to five, and occasionally up to ten, are the most useful ones. But I have made several with much higher powers; there being cases in which the highest power that the atmosphere will allow us to use, is desirable in obtaining representations of large buildings; such may be drawn of a large size, and from a distance so great as to reduce the perspective, practically, almost to a geometrical elevation; thus allowing the artist, without any considerable error, to measure the proportions of all the parts to each other; and in favourable situations high powers will bring many interesting subjects to us, that were scarcely noticed by the unassisted eye.

As the camera obscura and the graphic telescope are unlimited in their powers, a comparison between them may be of use. First, cameras, although unlimited in theory, are limited in practice—*i. e.* they may have many lenses of different foci, but we cannot make sketches of any intermediate sizes, because the paper must be put where the focus of the lens is. Not so with the graphic telescope: the paper may be put at any distance we please, and the image adjusted to coincide with it; therefore, the sketches made with one power may be varied in size anywhere between it and the next or the preceding power. Secondly, power for power, they both require the same accuracy of steadiness, because motion is magnified as much as the image. I have provided a light and portable table for the telescope, that is quite firm and steady, and the artist may rest his weight on it with impunity. I have never seen any portable cameras so steadily mounted, and with so little weight for out-door work, except the few which have been mounted on this table, and have thus overcome one of the objections to the use of cameras. The height of the table is arbitrary: I fix the one I use at that height which is most convenient to myself, and vary it to suit other persons; the telescope is eighteen inches above it, and takes the horizon about six feet high, and all is open to let the wind pass. These heights are fixtures, let the powers vary ever so much. An opaque camera, to equal the telescopic power of two, must have its lens twice as high above the table, and the space must be enclosed to render it dark; this exposes a broad surface to the wind; it is, therefore, more difficult to keep steady. A camera to equal the power of ten must have its lens placed fifteen feet above the table, and all must be enclosed to secure its darkness; such a camera would require a firm pyramidal structure to keep it steady against the wind, and it would require very considerable assistance to move from place to place, but the bulk and weight of such an instrument, whatever may be its intrinsic merits, would greatly interfere with its use, to say nothing of its great costliness. With the graphic telescope no image is projected on the table, but the rays are directed upwards into the eye in such a manner as to appear to come from the table; therefore the image does not depend upon any surface to render it visible, whether any part is adjusted to coincide with the drawing surface or not, it will be seen distinctly, and may be traced, or each part may, by adjustment, be made to coincide in succession, and then traced. It was shown by fig. 17 that when a lens projects an image as large as life, that image will be quite as convex as the original; the difference in the adjustment of the different parts is, therefore, so great that a very convex object cannot be shown as large as life in the opaque camera, though it may be in the transparent one. The telescope has no such inconvenience, for it was shown by fig. 18 that a reduced image is very much flattened, and even when the object drawn is as large as the original, that the first image is of necessity reduced as much as the eye-piece will magnify it, and the eye-piece does not alter the flatness which is imparted to it by the object-glass. Therefore, no inconvenience is felt when drawing as large, or even a little larger than life, for the greater the power of the telescope, the more completely flat does the image appear, in consequence of its requiring to be at first so much more reduced. This is a great advantage that the telescopic image has over others, and which for drawing, the telescope alone possesses. The field of view of this instrument, when at eighteen inches below the eye, is a circle of eighteen inches diameter, whether the power is much or little, but it may be as much larger as we choose to place the eye-piece above the paper or canvas. I have by this means had a six feet area, and marked out the sketch with charcoal at the end of a long reed stick, the paper and the telescope is therefore shifted for succeeding portions, and thereby we can make sketches several feet long. A camera obscura, whatever may be its power, can show the whole at once, if the table is big enough, though not all in adjustment at once. The transparent one, with a correcting lens, would show all in adjustment, but from the great size of the correcting lenses, and each power or object-glass requiring its own correcting lens, such an instrument would be very expensive and cumbrous.

This answers the question, how is it that such excellent instruments, which could so much assist the arts, are not more in use? If a drawing is made in a camera it cannot be coloured there, but it may be taken out and coloured, leaving white paper in the camera to receive the image that the drawing may be compared with it.

The image given in the graphic telescope is strictly correct as straight lines are given quite straight in all parts of the field, and the power can be set for any sized images we wish, without increasing the bulk in any degree worth naming, and the highest powers add very little additional weight to it; therefore, the graphic telescope offers a power and liberty to artists that cannot be afforded by any other instrument, it being so much cheaper and so much more portable than any camera could be that was sufficiently furnished to rival it: and sketches may be coloured with it, there being no image thrown on them, but the eye may alternately see both the image and drawing in the same place, and thus make a perfect comparison, so that the artist may keep working till the sketch appears to be a substitute for the original.

The flatness of images is a peculiar advantage in the telescope, their near and far parts being equally distinct for tracing; but all this excellence is reversed with the *graphic microscope*, the evil shown in fig. 17 is ten or a hundred times increased, by which the slightest difference in the distance of the objects will render one or one part visible, whilst the other is invisible. It therefore requires the most industrious attention and patience to draw well with the microscope, but with patience the difficulties may be overcome, yet the difference is so great that an artist could make five or six drawings with the graphic telescope to one with the graphic microscope.

From what has been said we may draw this conclusion, that the *camera lucida* and the *graphic telescope* are the most accessible instruments, and, together, afford everything an artist needs to enable him to obtain accurate sketches of any size and degree of perspective: they being portable enough to use in any place from which an artist can need to draw. And, because these exist people will be unwilling to incur the very great expense of efficient camera obscuras. Yet it would be very desirable to see a series of cameras produced that should be a complete rival to these more portable instruments, because every draftsman who sees a good image in a camera obscura feels sure that he can trace it. But with the camera lucida and my graphic telescope the correct adjustment of the image to the paper does not appear so obvious, for when they see the image quite well they are apt to neglect the adjusting it to the paper, although they cannot trace the minutiæ well without such adjustment, and if on this account their first attempts are imperfect, they are apt to give it up, fearing it may involve the acquisition of more optical knowledge than otherwise would be needful.

I will now show some of the advantages obtained by using this graphic telescope: premising that instruments not being masters, they cannot make artists of those who want the necessary previous knowledge and practice; but this instrument is a most excellent servant, and one that will greatly facilitate the progress of an artist.

In the first place, it sets him quite at liberty in the choice of the distance from which he will take his view, and also in the size of the sketches; for without such help we are frequently obliged to go much too near in order to see the leading features, and thus, by the violence of the perspective, lose much of the grandeur and true proportion. With the telescope there is no distance from which an artist would choose a view, but what it will show distinctly, and of any size that he could wish. When a back-ground is mountainous, sketching further off brings them up in much grander proportion, and thus the telescope finds numerous fine views, that before were unnoticed; intervening objects hiding them from a near view, and sometimes water removing us too far to see them large enough to claim our attention. In thus drawing attention to more distant views, I do not mean to neglect the grand and imposing effect so often obtained by a near view, where the artist is enabled, by the rapid increase of the perspective, to alter so much the apparent proportions of the object, as to render it greatly superior to its natural proportions as seen from a distance; but for these, drawing by the eye is frequently more convenient than with an instrument.

This telescope will give all the views strictly correct, without any care or anxiety about the perspective; it is therefore very valuable for drawing shipping and boats, the various curves of which cannot be known, yet are hereby given quite correct. Trees may be drawn more correctly, and with much more of the details, than otherwise we should have patience to attend to. Indeed, all local objects,—wagons, and the various implements of husbandry, which must be had, and yet are scarcely worth the trouble, animals, figures, and birds,—may readily be drawn; and by taking away the object-speculum, these objects or views may be drawn at once on stone the reverse way, and so be printed the right way: thus we may now publish real sketches from nature.

Wild or savage animals may be sketched from a place of safety, at such a distance as not to rouse or disturb them; also timid animals, which will not remain still if we go near them. In this case a good artist needs not always to trace; the image of the animal, or of a ship sailing, may be in one part of the field, and a copy made of it close by the image, which is a peculiar advantage when the object is in motion.

Portraits of any size may be drawn from life. To do this it is convenient to place the head of the sitter in contact with a V-shaped gap in a board, attached to the back of a chair.

The instrument is of great use for copying or reducing from statues or pictures, architecture or machinery. It also supplies with the greatest ease all those magnificent effects produced in mountain scenery by accuracy in the geological details of their surface.

Artists may also employ draughtsmen to sketch correctly the inferior details for them, and thus save their time to attend to the nobler parts of the art. Few flowers remain in the same state long enough to be drawn correctly, with the lights, shadows and reflections, caused by sunshine: with this instrument that may be done. Also the most minute botanical or entomological specimens may be drawn as large as needful to show the particular details.

If this telescope, table, and draughtsman, were mounted on a polar axis (a strong axis placed parallel to that of the earth), and moved by a clock a most perfect map of the stars could be traced, of any required size; for he would then direct his telescope to succeeding portions, as though they were all quite stationary.

A METHOD OF PRESERVING PICTURES IN WATER COLOURS.

MANY colours fade when used in water colours, which do not whilst kept in bottles. Skilful manufacturers soon learn the necessity of quickly drying their bright colours, and the prudence of drying all others, for the air or its impurities quickly acts on them whilst wet. Many, therefore, use artificial heat, by which they are rendered perfectly dry; if in this state they are bottled, they remain safe. But these colours have to be prepared for use by mixing them with gums of different sorts, which serve to keep them suspended in the fluid whilst laying tints of them on the paper, and also cause their adhesion to the paper when dry. The paper is also prepared with size, for the purpose of holding its filaments together, and to prevent the colours sinking in. Some of the colours are more acted on by wet gums than by moisture alone, and others really permanent are quite spoiled by the decay of their gum. I will state one fact out of many:—Colours are often prepared soft, for the readier use of artists. Having bought some bottles of these, after a while, there was one that I often took up as a rich brown, in which there was some small specks of white, on dipping the brush to take some out it had got stiffer than it should be, but the inside portion was white. The ordinary conclusion would have been that this pigment had changed colour, at least, over the surface; but no, it was really permanent white barytes. I placed some under the microscope which showed the white pigment as perfect as ever, but the gum and moisture had favoured the growth of a very minute fungi, or mildew of a rich brown colour, which covered the whole surface of the paint between it and the bottle. A large portion of this was in minute globules, arranged like beads, probably seed vessel, not more than the 5 or 6000th part of an inch big; there appeared to be nothing but this brown vegetation, and the white barytes. Had the pigment being nearer to the colour of the fungi, it would not have been noticed, only the colour would be found a bad laying one, and with little adhesion, from the gum having changed its nature.

Water colour pictures, as ordinarily framed, are exposed to continual alternations of moist and dry, as well as hot and cold, conditions which favour the dry rot, mildew, and decay, of both paper, size, and gum; and this involves the change of some of the pigments, and a dirtying of all. In addition to this, there is the bleaching action of light going on whenever there is moisture.

In order to prevent these various actions, I render the pictures as dry as possible, and also the space in which they are contained, and then prevent all further change of air by hermetically sealing them up in the following manner:—

Plate glass is preferable on account of its strength, its flatness, and freedom from colour. This being moderately well fitted to its seat in the frame, I fix it there by stiff white lead, ground in oil; but knowing this will not be impervious when dry, I make it so by adding copal varnish to it; with this I cover the seat in the frame, and also paint the edges of the glass, to secure a real contact with every part; the glass is then to be put in one end first, and gently lowered to let the paint come in close contact, and exclude air bubbles. Having pressed the glass down, and smoothed the fittings, I render some of this stiff paint thinner with copal, and paint the inside and back of the frame; thus uniting the glass to the frame in one continuous air tight surface; a strong back board whilst very dry is fitted to its place. When the paint is dry, and the glass made perfectly clean, I place the front of the frame, and also the back-board before the fire till it gets warmed through and has expelled all moisture : the drawing which was previously kept in a warm place, is carefully wiped with clean cloth to remove every loose particle, and then put in its place, and the back-board fastened in, (when paper is needed at the back to fill the space, that should be perfectly dried,) slips of strong brown paper are to be pasted round and over the fitting of the back-board ; the whole is then left to dry with the face towards the fire, by which means every particle of moisture will first leave the drawing, then the back-board and its pasting ; and when assured of its complete dryness, the whole back of the frame and board is to be well varnished over with oil copal ; it is then finished. This will shut up all the pores, and so exclude all future moisture, and consequently all chemical action. Pictures thus sealed up will endure with their original brightness as long as the frames and glass remain sound, and if the frames have been oil-gilt (as they should be), the dry wood will be perfectly inclosed in varnish, so it has no cause for decay. The pictures should not be disturbed for regilding the frames. In some cases the preserving frame may be made to fit into another which has all the ornament and gilding.

PICTURES IN OIL

Are exposed to nearly as much dirt as our windows, but for fear of damage we endure much more dirt on them than on the windows before we determine to clean them, the consequence is, that for two-thirds of their duration we behold them through a sickly brown-yellow film of dirt, which quite alters the silvery-grey and pale-purple tints, and which reduces the picture much below its original beauty. Added to this, the varnish most in use for pictures is the mastic, the weakest of all, and one that imbibes the brown dirt of a London atmosphere quite through its substance, so that dirt cannot be washed off. The turpentine, or spirit copal varnish, will not imbibe the dirt, therefore, it may be washed clean. In other respects the goodness of varnish depends on its absolute freedom from moisture, which retards drying and causes the bloom called chilling. Oil is also bad in enabling the varnish to imbibe the dirt instead of leaving it on the surface. I, therefore, never use any varnish that is made with oil for any outside surface. The two best varnishes known is the pure copal and the colorless lac varnish; either of these when dry completely shuts up the picture from any influence of the atmosphere; nothing passes through them, the dirt cau only lodge on their surface, and that may be removed by plain washing with flour and water, and if the dirt is more obstinate a thin coat of paste in the act of drying will stick to the dirt, and as soon as dry it may be softened with water and washed off, taking the dirt with it. Copal varnish, after washing, may have its gloss restored by a little varnish thinned with alcohol. There are many difficulties attending the use of oil, for no varnish will effectually protect but such as dry hard and brittle; if such varnish is put on a new picture before the oil has hardened, it is very liable to cause a cracking over the surface, but old pictures that have become hard, when they are effectually cleaned, may be preserved from all future wear and tear by a good covering of copal varnish, which can be cleaned without removal. New pictures, whilst the artist is living, are liable to retouching; if that is done over the varnish they will be liable to suffer in any future cleaner's hands. On this account, and for the sake of the pictures, it is often desirable to entirely remove the varnish; and this may be done without harm if we first use a water varnish that will not crack the picture, and then cover it with the varnish we esteem best. Isinglass or parchment glue are good mediums, but used alone would be very liable to crack the paint; I therefore soften either of these with carbonate of ammonia, white sugar, and the whitest soap;

these all tend to reconcile the watery coat to the oil or varnished surface, making it take better hold and spread easier. The soap softens this medium enough to hinder its cracking the picture, and the sugar improves the solubility and transparency. Having well coated the picture with this, let it be soon dried for the sake of keeping it clean, and then cover it with the proper varnish. Whatever the varnish may be, this double and dissimilar coating will insulate the picture effectually from the atmosphere, and at any future period both may be removed by rubbing with warm water and flour, which soon finds its way to the water varnish, and softens it enough to be washed off, leaving the picture quite as clean as when first put on.

Above I have only stated the means of keeping the picture clean and insulated from the atmosphere by one good varnish, or two dissimilar ones, by which their removal is much facilitated; but this is not enough, if the picture is not protected from being broken all over into thousands of small cracks. This cracking is often laid to the charge of the artist, or the materials he paints with, when the fault is not in the material but in the unprotected state of the canvas. It is left to swag about, when moved; or when cleaning, or dusting, it is bent in every part enough to cover it with minute cracks, at that time invisible, but which gradually become visible, and then the paint is blamed because it will not remain for ever flexible enough to bear such unnecessary usage: a back-board ought, therefore, to be fitted in close to the back of the canvas to support it against all rough usage of that sort. If a painting is hung high, it is eligible to slope it forwards to meet the eye, the canvas will then swag forwards and be shaken by motion of the air on opening doors or windows, the varnish always becoming brittle (otherwise it would not resist dirt) will crack by this motion of the canvas. I saw a picture, six feet wide, that had a good varnished face so placed and it began simmering all over like a tea-kettle previous to boiling. If the canvas had been stretched enough to prevent this swagging, that alone would have cracked the picture as much, and worse, in that it would open the cracks and sooner make room for dirt that can never be removed; all this may be prevented by covering the back-board with pitch and bees-wax, the very act of wiping or dusting the picture will press the canvas enough to cause its adhesion, and thereby prevent any future shaking, and above all, save it from being again stretched. Next, the canvas is usually left to decay. It appears a great oversight to place so much talent and property on canvas and then leave that to decay, for the size which is used to prepare the canvas for priming greatly contributes to the rotting of the canvas, it being exposed to every alteration of the atmosphere. This should be prevented by perfectly drying the canvas with the primed side towards the fire, and then varnishing the back to shut out all future moisture. A picture so preserved and having an adhesive back-board would endure for an unknown period.

P. S.—On the back of every picture there should be a statement of the last process to which its face was subjected in order to guide the next person who has to clean it.

CORNELIUS VARLEY.

THE END.

W. S. Johnson, "Nassau Steam Press," 60, St. Martin's Lane.

Varley's Optical Drawing Instruments.

Fig. 1.

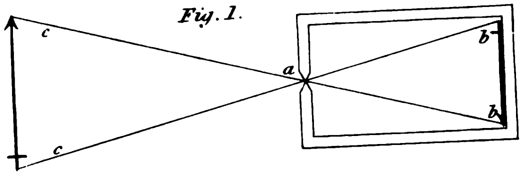


Fig. 3.

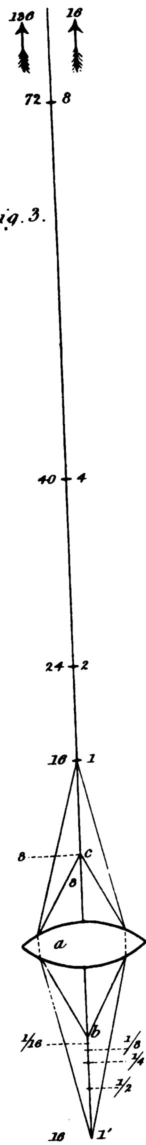


Fig. 2.

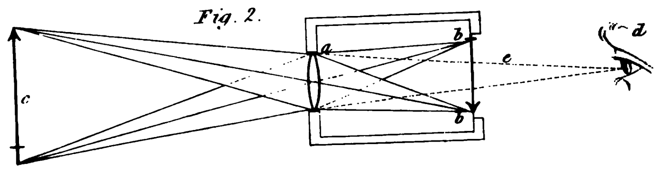


Fig. 4.

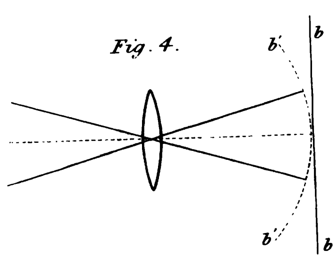


Fig. 5.

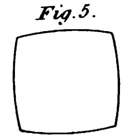


Fig. 6.

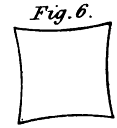
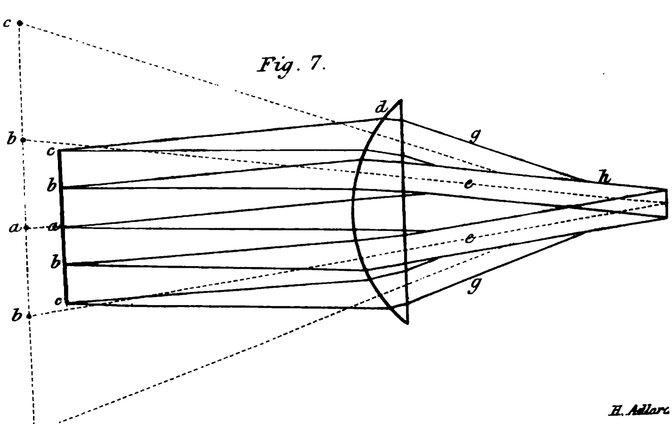


Fig. 7.



C. Varley. London · Horne & Co. Newgate Street, 1845. H. Adlard

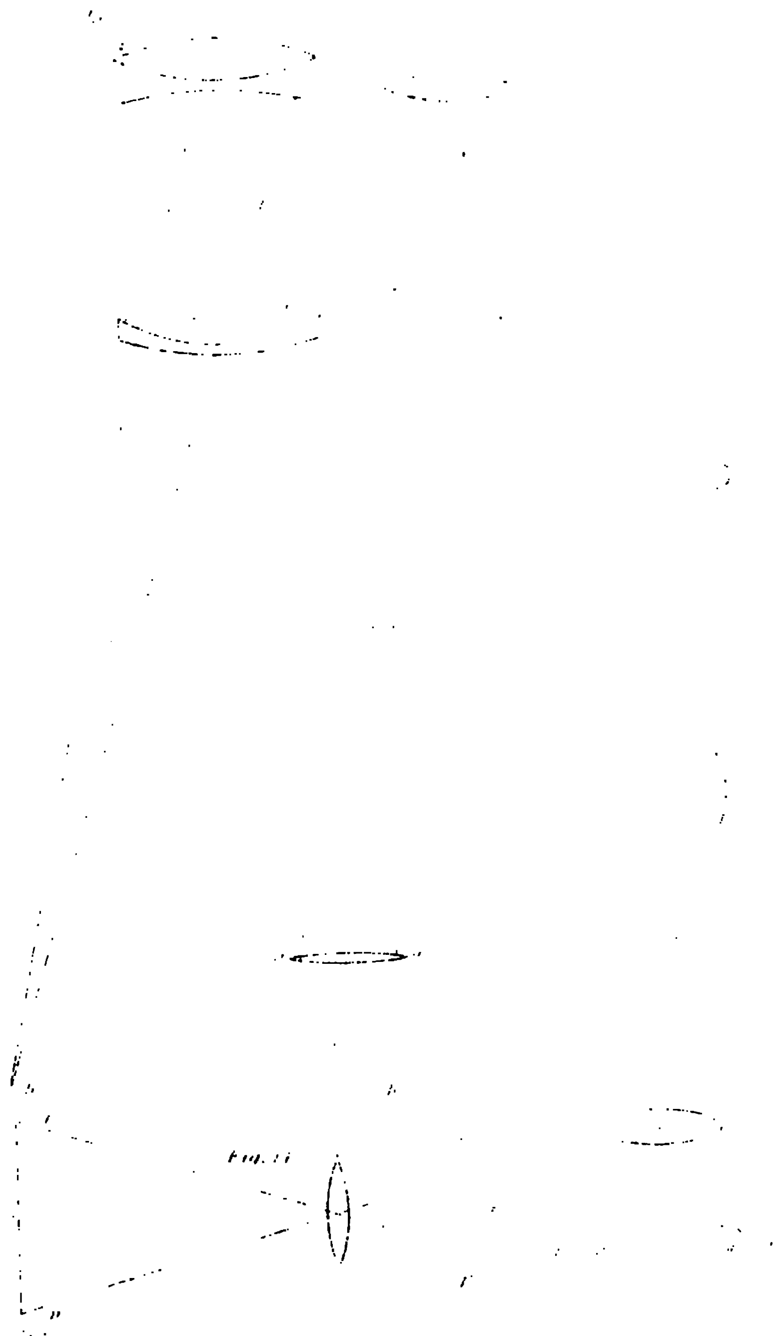
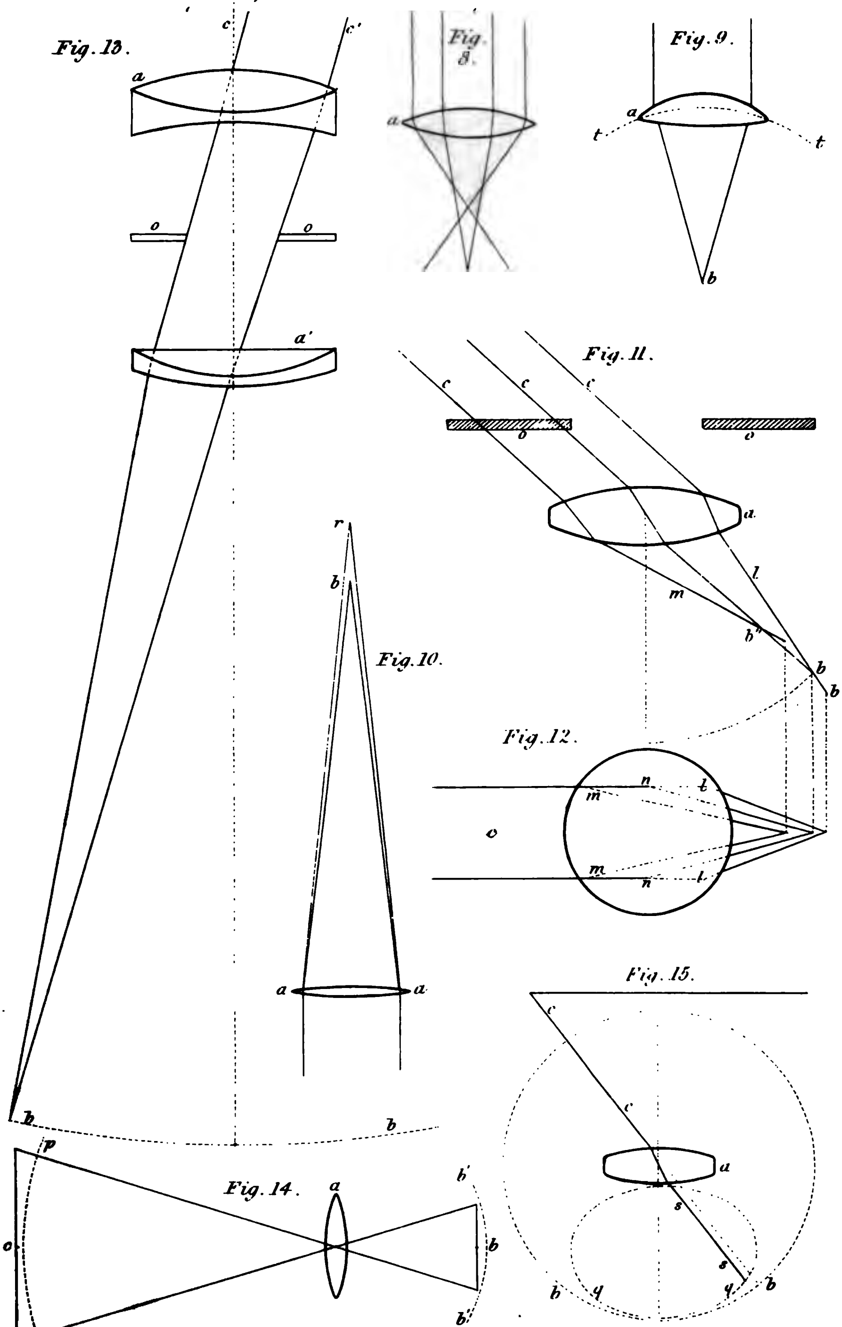


Fig. 11

Varley's Optical Drawing Instruments.



C. Varley. H. Adlard.

London. Horne & Co Newgate Street. 1845.

Varley's Optical Drawing Instruments.

Fig. 16.

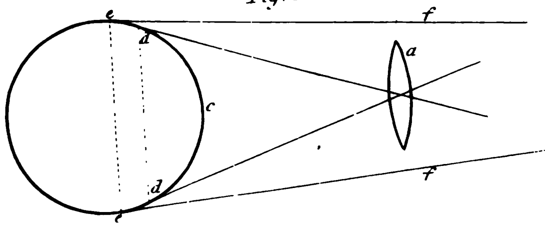
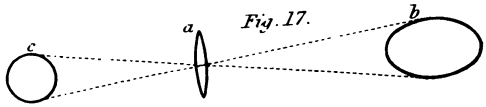


Fig. 17.



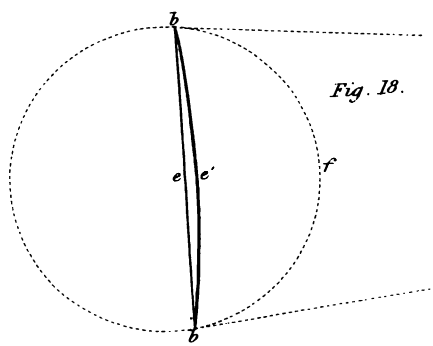


Fig. 18.

Fig. 19.

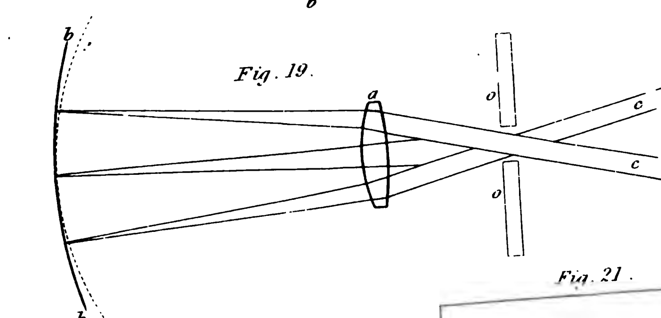


Fig. 20.

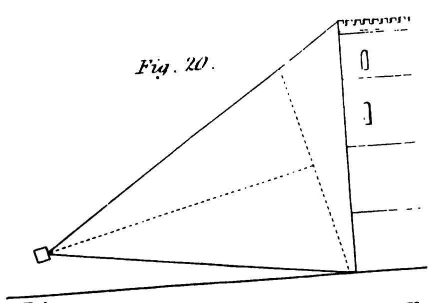
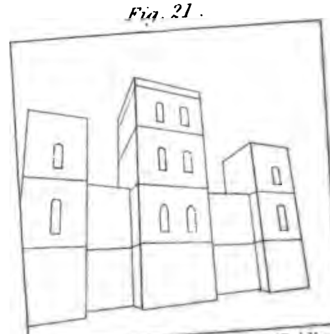


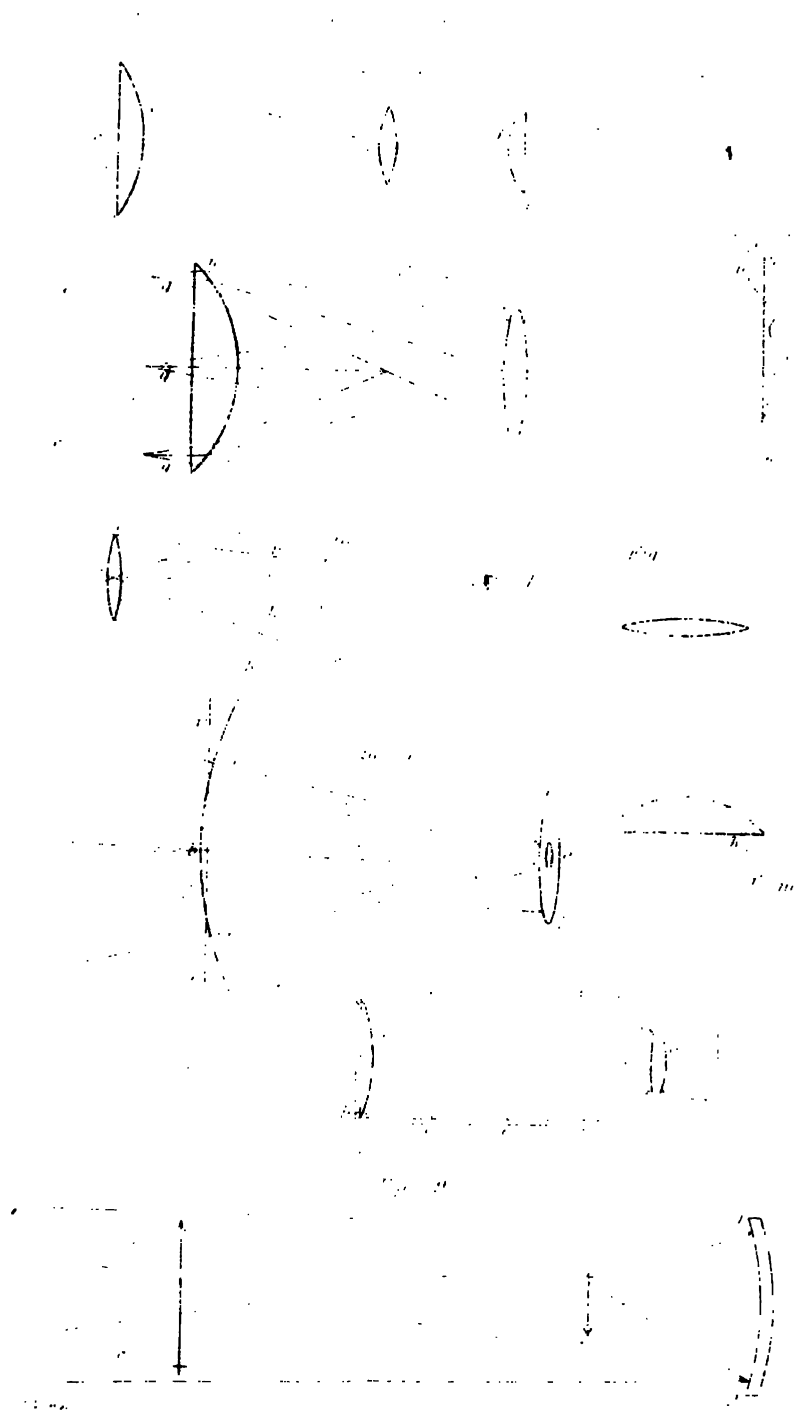
Fig. 21.



H. Adlard.

C. Varley.

London. Horne & Co. Newgate Street 1845



Varley's Optical Drawing Instruments.

Fig. 22.

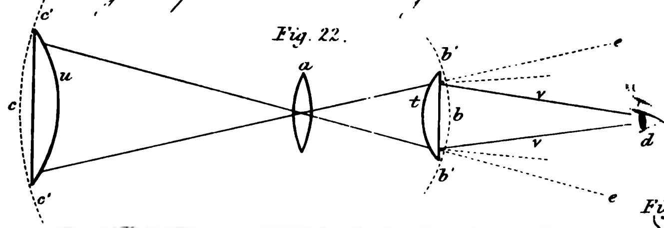


Fig. 23.

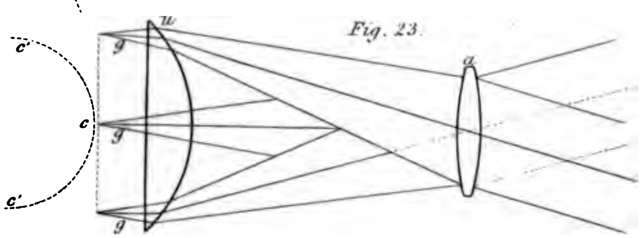


Fig. 26.

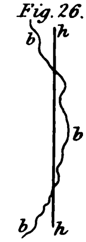


Fig. 24.

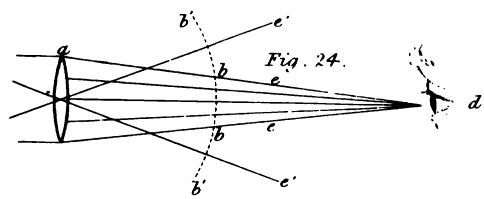


Fig. 25.

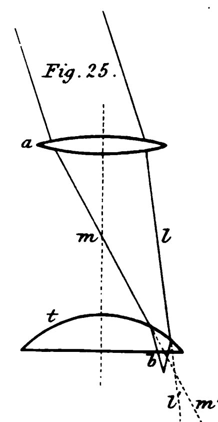


Fig. 27.

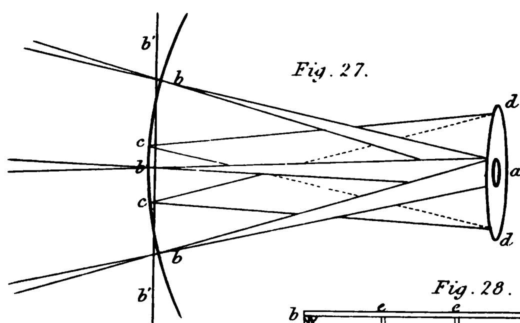


Fig. 28.

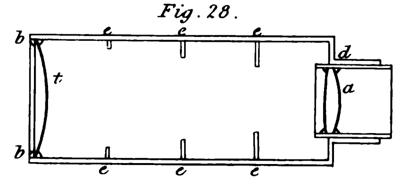
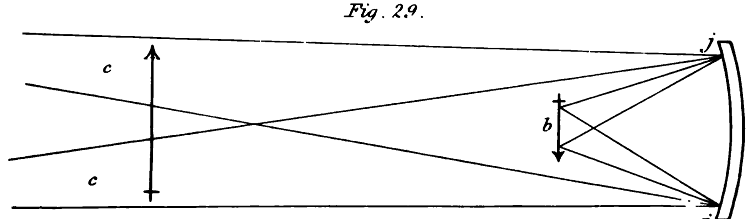


Fig. 29.



C. Varley. H. Adlard.

London: Horne & C° Newgate Street. 1845.

PLATE V.

Varley's Optical Drawing Instruments.

Fig. 30.

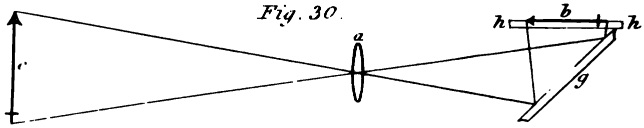


Fig. 31.

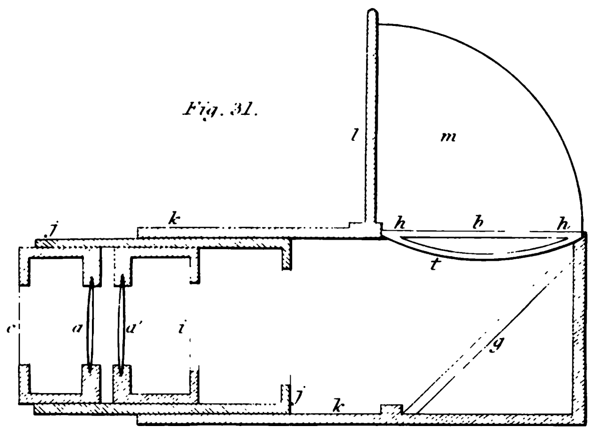


Fig. 32.

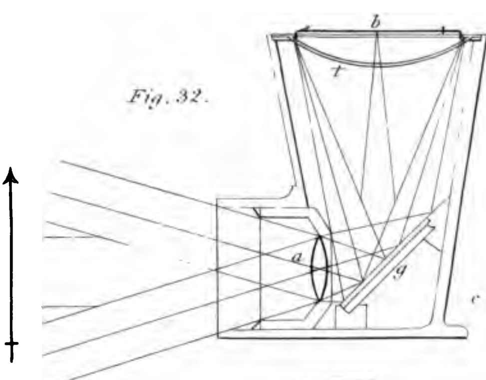


Fig. 34.

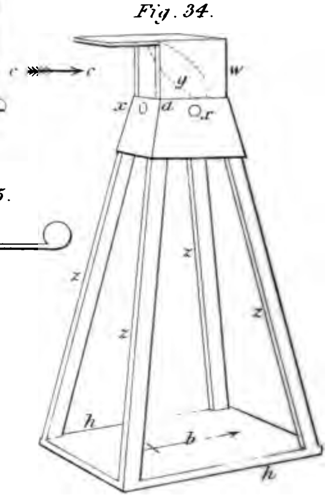


Fig. 35.

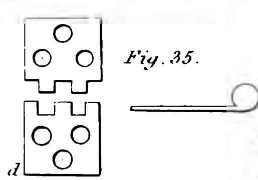
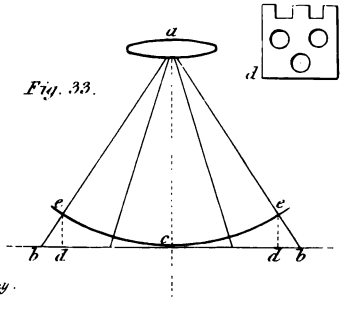


Fig. 33.



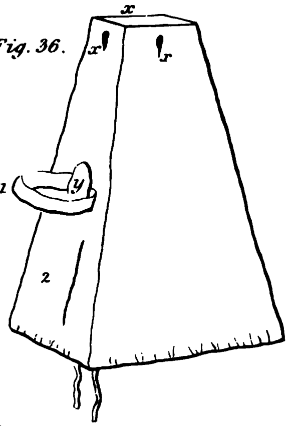
C. Varley. H. Adlard.

London: Horne & Co. Newgate Street, 1845

PLATE VI.

Varley's Optical Drawing Instruments.

Fig. 36.



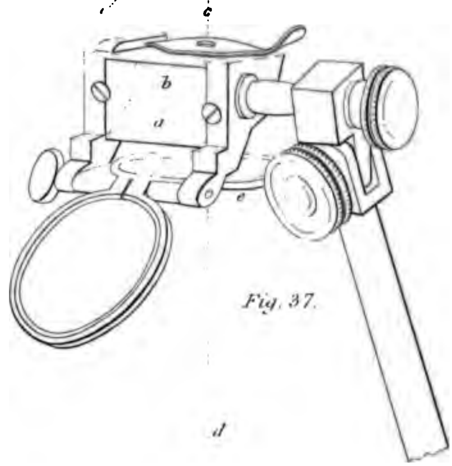


Fig. 37.

Fig. 38.

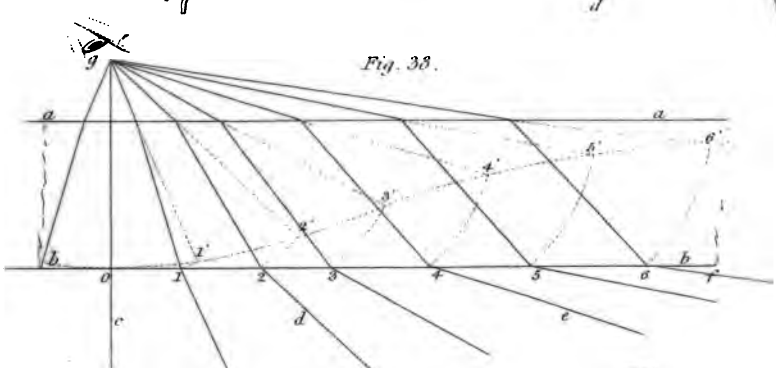
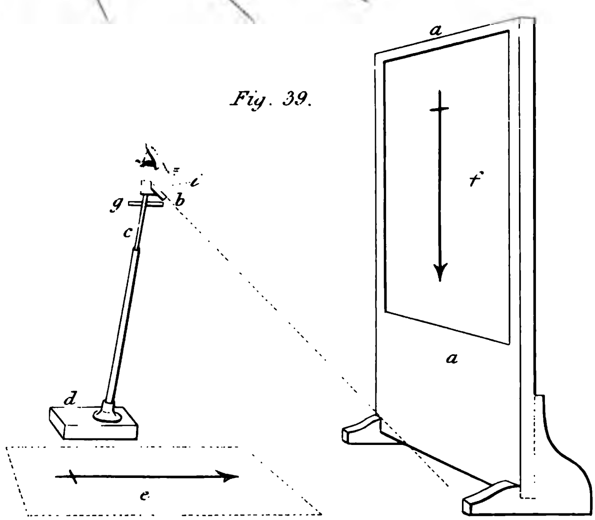


Fig. 39.



C. Varley. H. Adlard.

London: Horne & C°. Newgate Street, 1845.

Varley's Optical Drawing Instruments.

PLATE VII.

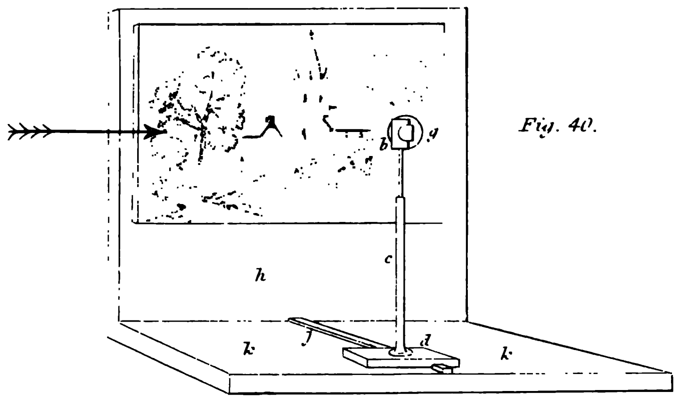
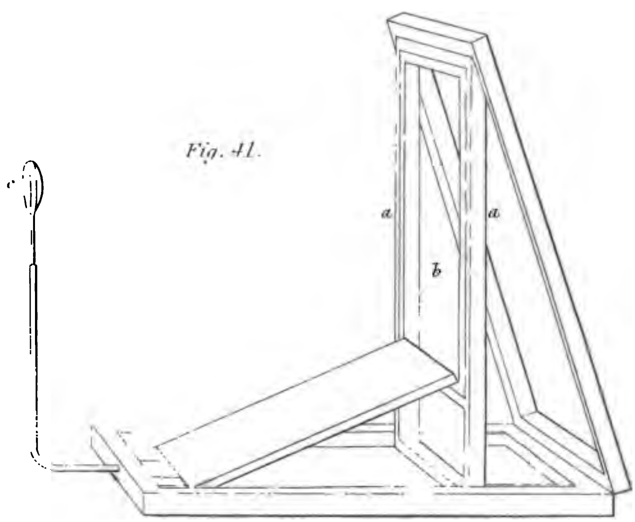


Fig. 40.

Fig. 41.



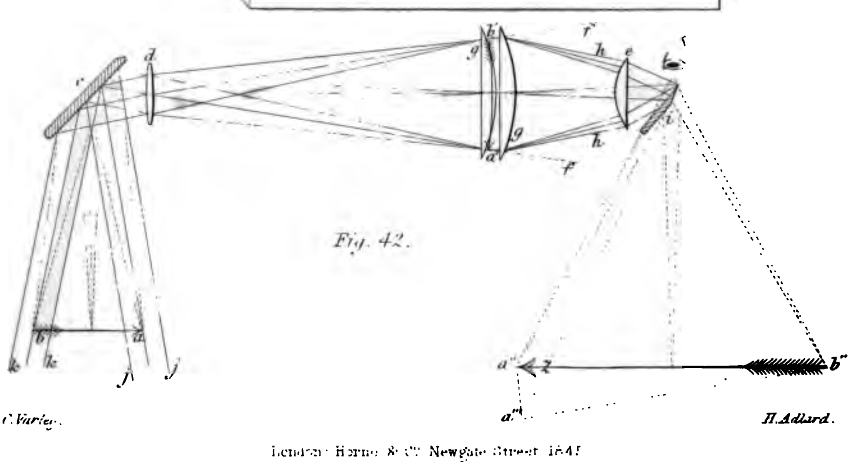
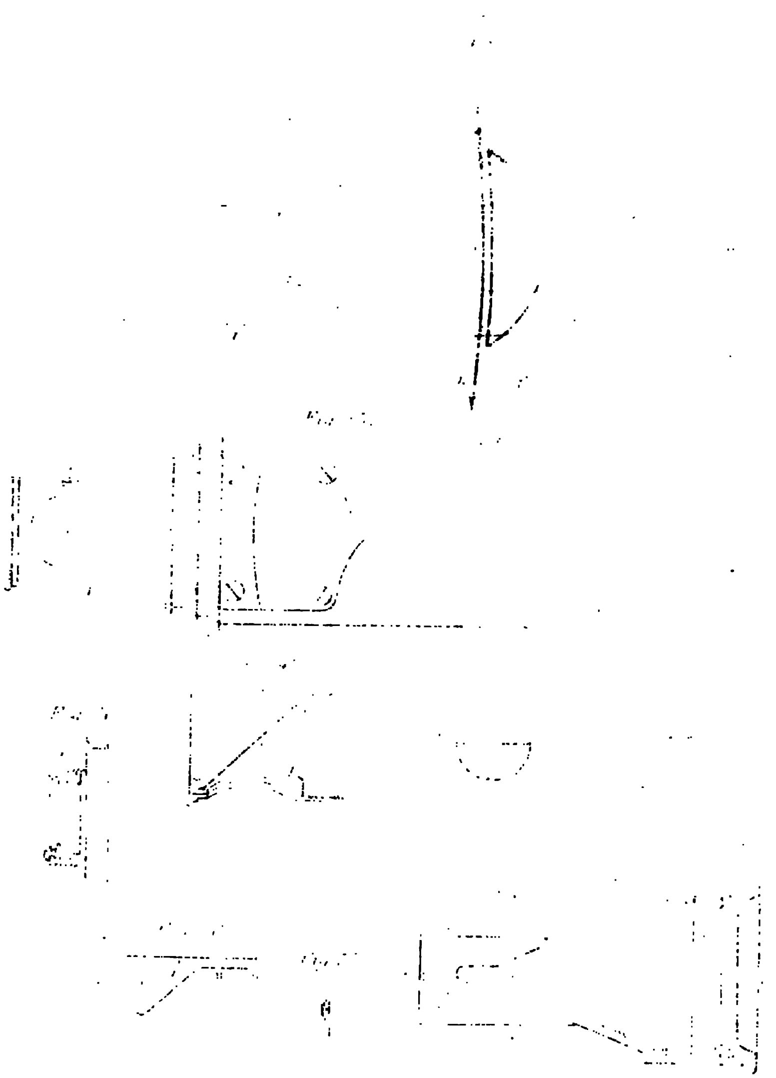


Fig. 42.

C. Varley.

H. Adlard.

London: Horne & Co. Newgate Street 1845



Varley's Graphic Telescope.

Fig. 43.

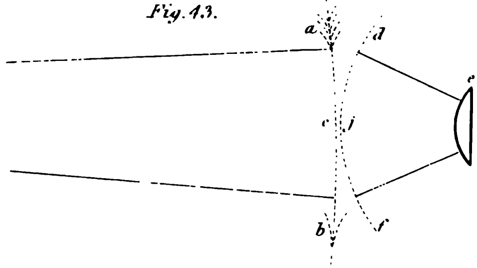


Fig. 44.

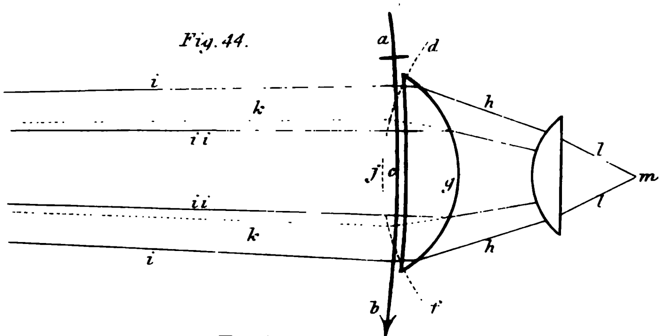


Fig. 45.

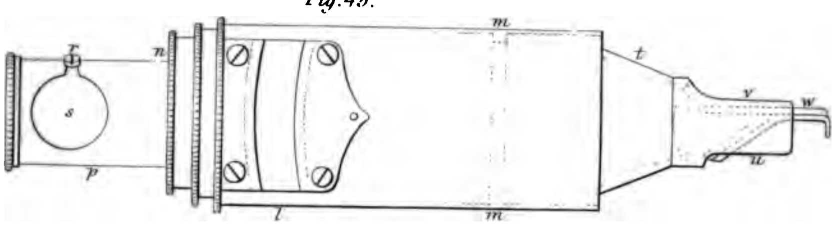


Fig. 46.

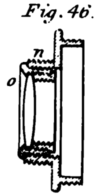


Fig. 47.

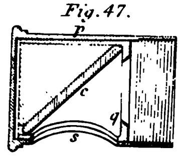


Fig. 48.

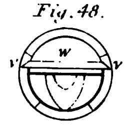


Fig. 49.

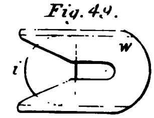


Fig. 50.

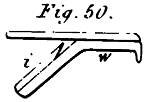
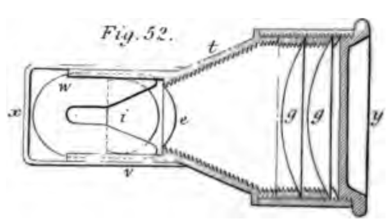


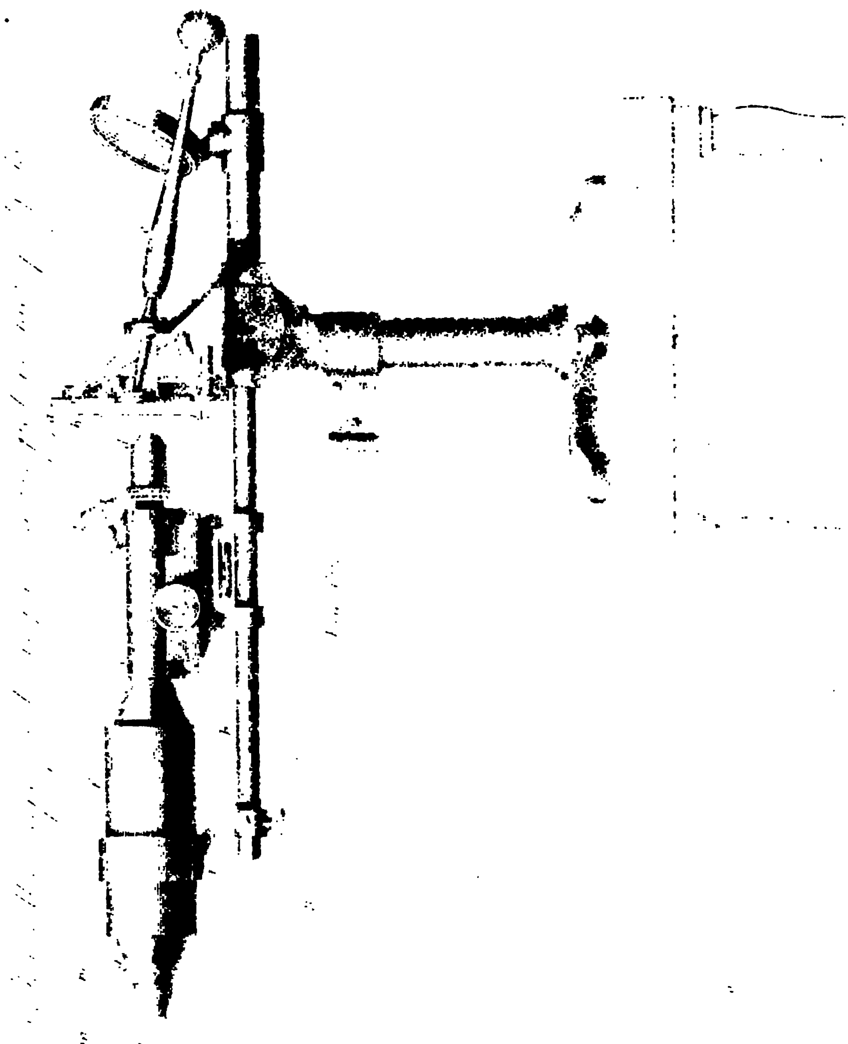
Fig. 51.

Fig. 52.



C. Varley. H. A. Ward.

London Horne & Co. Newgate Street. 1845



Varley's Microscope for tracing the magnified images of objects.

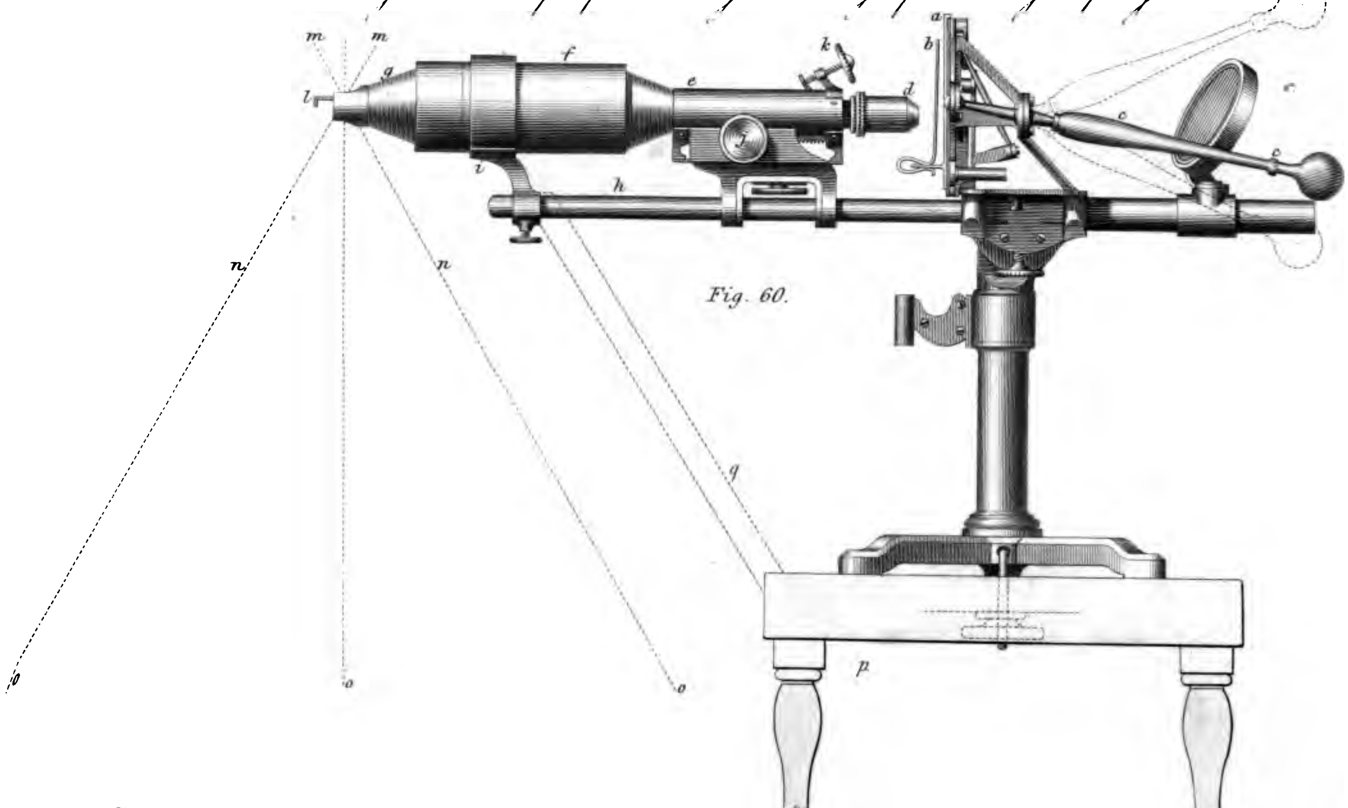


Fig. 60.

C. Varley. H. Adlard.

London. Horne & Co. Newgate Street. 1845.

"An interval not far short of 5' must be allowed as an interval of indistinct vision covered by the rim of the Spectacle, half of which must be subtracted from the field of vision above the glass, half from that part occupied by the glass. In the common form of Spectacle 5' must, in a similar manner, be subtracted from the rim at the bottom of the glass. In the Pantoscopic form, however, the lower interval falls at the extreme limit of the field, and is therefore of no consequence.

"From these measurements we at once perceive that the Pantoscopic differs from the common Spectacles, on account of the great extent of the field of vision above the range occupied by the lens, in which objects may be seen in their natural condition. They differ, moreover, from the small extent of field which exists below the bottom of the lens; and, in fact, this would not have any existence, as the Pantoscopic lens rests upon the cheek, did not the rounded and receding form of this part of the face have a small interval at the outer margin of the Spectacle.

"As a consequence of this arrangement, the Pantoscopic Spectacles occupy that part of the field actually employed in the examination of near objects, whilst that part, not required for that purpose, is left uncovered for the wearer to examine distant objects.

"*As a whole I am much delighted with these Spectacles, which are, in my opinion, of by far the best form that has hitherto been devised; and I have no hesitation in stating that you may recommend them as a safe and comfortable assistant to vision to all preslyopic, or far-sighted persons.*"

"ALFRED SMEE."

"MESSRS. HORNE, THORNTHWAITE, AND WOOD,
123, *Newgate Street.*"

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PATENT PANTOSCOPIC SPECTACLES.

Best Horn Frames, with Glasses	0	5	6
" Tortoiseshell ditto	0	12	6
Single Steel	0	7	6
Ditto ditto	0	12	6
Ditto ditto, with Pebbles	1	1	0
Turnpin ditto ditto	1	5	0
Single Gold, with Pebbles	2	15	0
Turnpins ditto ditto	3	3	0
Single Silver ditto	1	5	0
Turnpins ditto ditto	1	7	6

The above are mounted with the best Pebbles and Glasses, ground on PROFESSOR WOLLASTON'S principle.

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123, NEWGATE STREET, LONDON.

	£.	s.	d.
Photographic Camera, with Brass Sliding Front and meniscus Lens, for obtaining pictures on paper, 4 inches by 3, fig. 7, price	1	1	0
Ditto, of the best construction	1	15	0
Cundell's improved Camera for Calotype drawing, with divided Ivory Scale, fig. 8	3	3	0
Photographic Camera, fitted with a Single Achromatic Lens, Sliding Brass Front, suitable for both the Daguerreotype or Calotype processes . . . 25s. to	1	15	0
Ditto, ditto, of superior construction	2	2	0
Ditto, ditto, with Calotype Chemicals and Apparatus	3	3	0
Ditto, ditto, with Daguerreotype Apparatus and Materials, complete in Case	5	5	0
Ditto, ditto, with Achromatic Lens, and fine rack-work adjustment front, for pictures, 4 inches square	2	10	0
Ditto, of best construction	3	3	0
Ditto, ditto. with Calotype Apparatus and Chemicals . . 3*l.* 16*s.* to	4	4	0
Ditto, ditto, with Daguerreotype Apparatus and Materials, in case . . . 6*l.* 10*s.* to	7	7	0
Ditto, ditto, for Pictures, 5 inches square	3	13	6
Ditto, ditto, ditto, 6 ditto,	5	5	0
Ditto, ditto, ditto, 8 ditto	8	8	0
Photographic Camera, with best compound Achromatic Lens, 1¾ inch diameter, fig. 11	5	15	6
Ditto, ditto, complete in Case, with every requisite for obtaining Daguerreotype pictures, 2¾ inches by 3¼	10	10	0
Ditto, ditto, with best compound Lens, 2 inches diameter	8	8	0
Ditto, ditto, complete, with all the necessary Apparatus and Chemicals for obtaining pictures by the Daguerreotype process on plates, 2¾ inch by 3¼, and 3 inch by 4, in lock-up case	15	15	0
Ditto, ditto, for plates, 8½ inch by 6½	35	0	0
Achromatic Lenses of the best quality, 1¼-inch diameter			
Ditto 1½ "			
Ditto 1¾ "			
Ditto 2 "			
Ditto 2¼ "			
Double Achromatic Lenses, 1¾ in diameter mounted in Brass front, with rack-work adjustment, fig. 13	3	13	6
Ditto, ditto, with Lenses, 2 inches diameter	6	6	0
Parallel mirror, mounted in Brass Frame, for reversing the picture			

		£.	s.	d.
Prisms for Parallel Mirrors				
Iodine Boxes		0	10	0
Mercury Boxes	from 15s. to	1	10	0
Iodizing and Bromine Pans, made of hard-glazed Porcelain, with air-tight covers	from	0	2	0
Ditto, ditto, in Mahogany or Walnut cases with Levelling Screws, frames for holding various sized plates, and Plate Glass cover		1	10	0
Graduated Glass Syringes for ditto		0	2	6
Plate Boxes, for plates, 2½ inches by 2		0	4	0
Ditto, ditto, 2¾ inches by 3¼		0	5	0
Ditto, ditto, 3 inches by 4		0	5	6
Plate Holdrs	from	0	3	6
Glass and Brass Spirit Lamps	from	0	2	0
Tripod Camera Stands	2 2 0 and	3	3	0
Brass Stands, with Levelling Screws	each	0	5	6
Velvet Buffs	each	0	2	6
Glasses to indicate from 5 seconds to 1 minute in leather case, each		0	2	6
Frame and Glass for obtaining positive photographs, or copying engravings, leaves, &c.	from	0	5	0
Camels's hair Brushes	1s. 2s. and	0	2	6
Glass Graduated Measures	1s. 6d. 2s. and	0	2	6
„ Funnels	from	0	0	6
„ Stirring Rods	from	0	0	3
Scales and Weights, with Glass Pans		0	18	0
Silvered Plates of the best English manufacture:				
2½ inches by 2 inches,	per doz.			
2¼ „ by 2¾ „	„			
4 „ by 3 „	„			
Paper, Composition and Leather Frames, for holding daguerreotype pictures				
Tin Stills, with worm tub, complete	from	1	5	0
Copper ditto, ditto, ditto	from	2	2	0
Paper for Calotype purposes, made by Whatman, Turner, & others				
Iodine	per oz.			
Do. pure	„			
Do. Tincture	„			
Do. Chloride	„			
Do. Bromide	„			
Bromine, pure	„			
Distilled Mercury	per lb.			
Hyposulphite Soda	per oz.	0	0	6
Chloride Gold Solution	„	0	5	0
Chloride Gold Chryst				
Nitric Acid, pure	„	0	0	4
Prepared Tripoli	„	0	0	6
——— Lamp Black	„	0	1	0
Hyposulphite Gold Solution	„	0	0	3
Pure Gallic Acid	„	0	10	0
„ Succinic Acid	„	0	10	0
Bromide Potassium	„	0	5	0
Strong Solution Ammonia	„	0	0	4
Proto Sulphate Iron	„	0	0	4
Pure Cyanide Potassium	„	0	2	0
Oil of Lavender				
Prepared Cotton Wool	per lb.	0	5	0
Iodized Paper, in Packets	1s. and	0	2	6
Photogenic Paper, ditto	1s. and	0	2	6
White Blotting Paper	per quire	0	1	6

CHEMICAL AND PHILOSOPHICAL APPARATUS.

CHEMISTRY.

		s.	d.		£	s.	d.
Alembic's Glass, ½ pint to 2 qts.		5	0	to	1	0	0
Alembic's Earthen	from	3	0				
Argand Lamps	each	6	0		0	8	0
Ditto ditto, with double Concentric Wick					0	15	0
Alkalimeters	each				0	6	0
Boxes of Fragments for the Blowpipe	per set				0	2	0
Bladder with Ferrule		2	0	to	0	3	0
Ditto with Stop Cock		5	0	to	0	6	6
Bars of Copper, Zinc, and Iron	from	0	6				
Brass Tripod Stands					0	1	6
Black Lead and Porcelain tubes for furnaces	from	1	0				
Bent Tubes of every description made to order							
Brass Pipe for blowing Gas Bubbles					0	2	6
Blowpipes common	from	0	6				
. . . . Pepy's		6	0				
. . . . Wollaston's		6	0				
. . . . Black's		2	6				
. . . . Bergman's		5	0				
. . . . Gurney's Oxy-Hydrogen					2	2	0
. . . . Self-Acting Spirit, Brass					1	10	0
. . . . Ditto, Tin		6	0				
. . . . Bellows with Table, &c.,	from				3	3	0
. . . . Hemming's Jet					0	9	0
. . . . Tilley's Hydraulic		21	0	to	1	5	0
. . . . Ditto ditto, very superior					2	2	0
Balloons	each from				0	1	6
Bell Air Jars, Glass, with ground Stoppers for collecting the Gases	each 2s. 6d.	3	3		0	4	0
Ditto, ditto mounted with Brass Caps and Screws, for the reception of Air Cocks and other Apparatus, each, pts. 4s. qts. 5s.							
Ditto graduated	from	3	6				
Cut Air Jars, per nest of 6					0	8	6
Ditto ditto larger					0	10	0
Crucibles, Cast Iron	each	0	6	to	0	3	0
Ditto Hessian and English	in nests	0	3	to	0	1	0
Chemical Scales	from	5	6				
Ditto ditto with Decimal Weights	from				3	8	0
Chafing Dishes	each from	12	0				
Crucible Tongs	from	1	6				
Covered Copper Wire	per lb.	4	0	to	0	12	0
Copper Basins	from	1	9				
Copper Sand Baths	from	2	0				
Iron ditto	from	7	0				
Cubic Inch Tubes	each				0	5	0
Caoutchouc, in sheets	each	1	0				
. . . . . Tubing,	per ft. from	1	6				
. . . . . Varnish	per oz.	0	4				
Copper Stills, with Furnace, Tub, &c., complete,	from				5	5	0
Cuff's Scale of Chemical Equivalents		5	6	to	0	6	6
Cement for attaching Brass Work to Glass Apparatus, lb.					0	2	0
Cryophorus	each				0	4	0
Bottles, Stoppered of all dimensions							
Ditto ditto with Glass Caps, for Acids, Volatile Fluids, &c.	from	2	0				
Ditto Woulfe's	each pt.	2	6	qt.	0	8	6

		s.	d.		£.	s.	d.
Ditto Specific Gravity	each				0	1	6
Bottles, Specific Gravity, Stopped and Graduated to 1000 grains, in Tin Case with Counterpoise Weight					0	8	6
Connecting Pieces and Ferrules, Brass	each				0	0	10
Candle Bombs	per doz.				0	0	4
Decimal Weights, complete set of, in Mahogany Box					1	10	0
Deflagrating Ladles	each				0	0	6
Deflagrating Ladle and Air-Tight Collar		2	6		0	3	6
Davy's Safety Lamp	each				0	10	6
Dropping Tubes		0	4		0	0	6
Elegant aud very useful Apparatus for experiments, with the mixed Gasses upon Lime					1	0	0
Eudiometers, Ure's					0	8	6

Evaporating Dishes of real Wedgwood-ware, not liable to crack or stain—

	s.	d.		s.	d.
2 in. over, each	0	4	7 in. over, each	1	8
3	0	6	8	2	0
4	0	9	9	2	6
5	1	0	10	3	0
6	1	4	11	3	9
			12	4	6

		s.	d.		£.	s.	d.
Flasks, ¼ pint		0	5				
. . . ½ pint		0	9				
. . . pint		0	10				
. . . quart		1	3				
. . . with Bent Tubes for generating Gases		5	0	to		8	6
Filtering Paper	per lb.					1	4
Funnels, Glass and Porcelain	from	0	6				
. . . Long Necked, bent Glass	from	2	0	to		3	6
Furnaces, Black Lead	from	10	6				
. . . . French		21	0	to	1	10	0
. . . . Knight's					4	10	0
. . . . Round, very complete					3	3	0
. . . . Dr. Black's					4	15	0
Furnace Stoves, for experimental purposes, made to order							
Fire Clay and Lutes	per lb.	0	6				
Fountain and Jets	from	63	0	to	5	5	0
Glass and Enamel Rods	from	0	3				
Glass Tubing	per lb. from	2	4			3	6
Ditto, Green, free from lead		3	6				
Gauge for shewing the expansion of Metals by heat						5	0
Hydrogen Lamps	21s.	30	0		2	2	0
Hope's Eudiometer						10	6
High Pressure Boiler and Stand, with Barometer Tube, Thermometer, and Lamp, complete					3	3	0
Horizontal Revolving Jet, for exhibiting Philosophical Fire-Works with Hydrogen Gas		7	0				
Hydrometers from		7	0				
Lactometers, for ascertaining the relative value of Milk	per set					14	0
Mortars, Agate	from	5	0	to	2	2	0
Ditto, Iron	from	1	6				
Ditto, Composition—							
No. 0000						1	3
000						1	6
00						2	0
0						2	3
1						2	6
2						3	0
Ditto Glass	from					2	0
Muffles, Earthenware	from	0	6				
Mercurial Troughs Mahogany	from	6	0				
Ditto ditto Iron	from	6	0				
Models of Chrystals in Wood	per set					7	6
Ditto ditto in Glass	per set					18	0

		s.	d.		£	s.	d.
Measure Glasses, 2 oz.		1	6				
3 oz.		1	9				
4 oz.		2	0				
6 oz.		2	3				
8 oz.		2	6				
16 oz.		3	6				
20 oz.		4	0				
One Gallon Tin Still, with Worm and Tub complete		21	0		1	5	0
Pneumatic Troughs of various sizes	4s. 6d.	10	6			16	0
Pepy's Improved Gas Holder, which, with the addition of a Jet, forms a most convenient Hydraulic Blowpipe	30s. 42s.	52	6		3	3	0
Ditto small Balneo, or Filter Bath, for drying precipitates and other explosive compounds, at a heat not exceeding 212o Far						10	0
Plates of Glass for covering Air Jars		0	6	to		2	6
Precipitating Glasses, ¼ pint						0	9
½ pint						1	0
Palmer's Oxhydrogen Jet	each				1	1	0
Ditto, with Bladders, &c.					2	2	0
Chemical Amusement and Instruction Chests, in great variety	from	21	0	to	20	0	0
Platinum Spoons	from	1	6				
Ditto Forceps	from	3	0				
Pulse Tubes	each					1	3
Quill Receivers	from	1	8				
Retorts, Glass, Plain—							
¼ pint		0	8				
½ pint		0	10				
pint		1	0				
quart		2	0				
3 pints		2	6				
2 quarts		3	0				
Ditto ditto Tubulated—							
¼ pint		1	4				
½ pint		1	8				
pint		2	4				
quart		3	9				
3 pints		4	9				
2 quarts		5	3				
Receivers, Glass Plain—							
¼ pint		0	9				
½ pint		0	10				
pint		1	4				
quart		1	9				
3 pint		2	6				
2 quart		3	6				
Receivers, Glass, Tubulated—							
¼ pint		1	2				
½ pint		1	8				
pint		1	6				
quart		2	6				
3 pints		3	9				
2 quarts		4	3				
Green Glass Retorts	from		10				
Retorts, Earthenware							
Ditto ditto Tubulated							
Ditto Cast Iron, with connecting Tube for the production of Oxygen and other Gases,	each					10	0
Retort Stands, Iron, with 3 sliding Rings,	each					7	6
Ditto ditto Brass, ditto		8	0	to		14	0
Reflectors, for experiments on Radiant Heat, of highly polished Zinc					2	2	0
Rupert's Drops	per doz.	0	6				

					£.	s.	d.
Spirit Lamps, Glass	2s. 3s.	4	0			5	0
Ditto ditto Brass						7	0
Ditto ditto with Concentric Wick and double Current of Air, on Professor Rose's principle, mounted on a Stand					0	18	0
Thornthwaite's Analysis Lamp					2	2	0
Stills, Working Models of		30	0		2	2	0
Syphons, Glass						2	6
Ditto Pewter and Copper with Stop Cock,	from	7	0				
Stop Cocks, Brass	each					3	0
Small Iron Wire, for combustion in Oxygen Gas							
Steel Crushing Mortars and Pestles	each					14	0
Thermometers	from	4	6				
Ditto Chemical	from	15	0				
Test Glasses—							
1½ oz.	per doz.					7	0
3 oz.						8	0
5 oz.						9	0
7 oz.						10	0
Test Tubes	per doz.	2	0	to		3	6
Ditto ditto Stands	from	1	0				
Test-tube Holders						0	6
Tube Retorts		0	6	to		0	10
Tubes, Earthenware	from	0	9				
Test Papers of Litmus and Turmeric	each	0	1				
Woulff's Apparatus of three bottles, with three necks each, mounted with conducting and safety Tubes in a mahogany Tray,	pints	16	0				
Ditto ditto	quarts	20	0				
Water Hammers	each	4	0				
Welter's Tube of Safety	each					2	0
Watch-glass Holders	each					0	6

Every description of pure Chemical Re-agents and Tests.

ELECTRICITY.

	£.	s.	d.
Small Cylinder Electrical Machines	1	5	0
2nd. Size	2	2	0
3rd. do.	3	10	0
4th. do.	4	10	0
5th. do.	6	0	0
6th. do.	8	0	0
9-in. Plate Machines	3	3	0
12 ditto	4	10	0
16 ditto	7	10	0
24 ditto	12	0	0
Set of 5 Spirals	2	2	0
Spiral on Foot		8	6
Hand Spiral		5	6
Diamond Spotted Jars 8s. 6d. to		15	0
Star in Frame		8	6
Bird in Frame		8	6
Luminous Conductors from		10	6
Magic Picture		7	6
Flask		6	6
Spider Jar		8	6
Cuthbertson's Discharger	2	2	0
Universal ditto	1	10	0
Jointed ditto		10	6
Gamut of Bells	1	16	0
Set of Five ditto		18	0
Set of Three ditto		7	6
Air Cannon 12s.		18	0

	£.	s.	d.
Air Pistol		4	6
Powder Cannon		5	6
Sportsman	1	5	0
Thunder House		9	0
Powder ditto	1	1	0
Obelisk		7	0
Egg Stand		9	0
Image Plates		9	0
Pith Ball Stand		5	0
Gold Leaf Electrometer		16	0
Lane's ditto		7	0
Cavallo's ditto		15	0
Quadrant ditto		7	0
Leydon Jars from		3	6
Pith Balls, per doz. 1s. to		2	0
Pith Figures, each, from		1	0
Head of Hair		7	0
Electrophorus from		10	6
Batteries from		10	0
Insulated Stools from		10	6
Amalgam per box		1	0
Bucket and Syphon		5	6
Electrical Cylinders from		3	6
Glass Handles		1	3
Legs		1	6
Pocket Electrical Bottle, and Riband for charging the same		7	6

BATTERIES OF ALL SIZES.

PNEUMATICS.

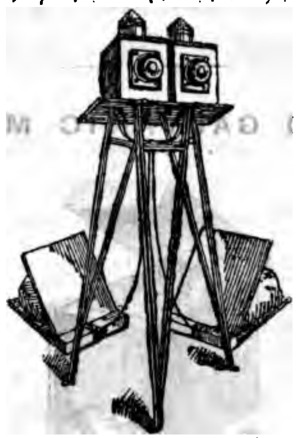
		£.	s.	d.
Single Barrel Air Pump with Receiver	21s. 25s.	1	10	0
Ditto ditto with Fountain		2	5	0
Small Size Double Barrelled Pump	3l 10	4	14	6
Middle Size Ditto ditto		7	7	0
Ditto with Guage Plate		8	8	0
Ditto with Raised Plate		9	9	0
Large Size Double Barrelled Air Pump		12	12	0
Ditto on Stage Stool		19	0	0
Single Transferer			26	0
Double ditto		2	2	0
Guinea and Feather Apparatus, 3 falls		1	4	0
Ditto ditto, 2 falls			16	0
Syringe and Lead Weight			12	0
Fountain in Vacuum, best make			15	0
Ditto ditto common			7	6
Lungs Glass			7	6
Bladder Frame and Lead Weights			7	6
Filtering Cup			6	6
Fruit Stand			5	0
Wheel and Upright Barometers	from	3	3	0
Open Receivers for Air Pump	from		3	6
Bladder Glass for ditto			3	6
Model of a Water Pump, showing the principal and absurdity of the term Suction	21s.	1	10	0
Ditto of Forcing ditto		2	15	0
Large Size Hemisphere		1	10	0
Middle ditto			18	0
Small ditto			15	0
Bacchus		1	8	0
Wind Mills on a new and superior construction		3	3	0
Copper Bottle, Beam and Stand		2	15	0
Bell Experiment	from 10s. to	1	1	0
Exhausting and Condensing Syringes			7	0
Ditto in one Instrument			10	6
Pocket Condensers for Instantaneous Light			3	6
Sliding Wire, and Collar			12	0
Ditto ditto, Thornthwaite's Improved, with Ball and Socket Joint			17	6
Model of Diving Bell		1	5	0

GALVANISM or VOLTAIC ELECTRICITY.

		£.	s.	d.
Cruikshank's Batteries, in Mahogany Troughs, for medical purposes—				
25 pair of plates, 2¼-inch		1	1	0
50 ditto ditto, 2¼-inch		1	15	0
200 ditto ditto, 2¼-inch		5	10	0
50 ditto ditto, 3-inch		2	10	0
25 ditto ditto, 4-inch		2	8	0
Grove's Platinum Batteries, excited with dilute muriatic acid in connexion with the zinc, and strong nitric acid in connexion with the platinum	from	1	15	0
Smee's Batteries, in round earthenware pots. so constructed that the zincs can be readily replaced by means of a binding screw, without the trouble of soldering or bending—				
Pints			10	0
Quarts			12	6
4-Quart		1	5	0
6 pint ditto, in mahogany tray, so constructed that they may be arranged for quantity or intensity, with flexible conducting wires		3	3	0
6 quart ditto ditto		3	17	6
Ditto ditto, in Wollaston's troughs of 12 cells with double zincs, and the silver plates, presenting a surface of 252 square inches		5	5	0
Ditto ditto, of 432 inches		6	6	0

Every description of Apparatus connected with Magnetism and Electro-Magnetism.

DISSOLVING VIEWS.



IMPROVED APPARATUS

FOR EXHIBITING

THE DISSOLVING VIEWS,

AS SHOWN AT THE

ROYAL POLYTECHNIC INSTITUTION

MANUFACTURED BY

HORNE, THORNTHWAITE, AND WOOD,

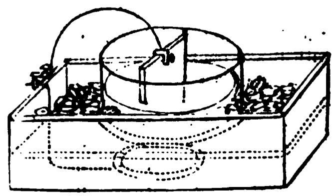
(Successors to E. Palmer)

123, NEWGATE STREET, LONDON.

Complete Apparatus, with Lenses 3 inches diameter, illuminated with Argand Oil Lamps, capable of showing a disk 9 feet in diameter		10	10	0
Views for ditto . . . . from . . . . each	7 0 to	0	20	0
Dissolving View Apparatus, illuminated with the Oxyhydrogen or Lime Light, capable of showing pictures 20 feet diameter, consisting of a pair of Mahogany Lanterns, with brass fronts, and dissolving apparatus, 2 pair of 4 inch Lenses or Condensors, 2 Oxyhydrogen Jets, and Lime Burners, flexible tube connections, 2 large India Rubber Bags and Pressure Boards, Lead Bottle Tube and Purifier, for making Hydrogen Gas, Iron Retort, &c., for Oxygen Gas, Folding Mahogany Tripod Stand, &c., complete . . .		42	0	0
Ditto ditto with 6 inch condensers .		60	0	0
Ditto ditto 9 inch ditto .		85	0	0
Views for ditto from 25s. to 80s. each, and upwards.				
Oxyhydrogen Microscope, with objects fitted to the above . . . . from		15	15	0
Ditto ditto complete, with the gas apparatus, &c.		35	0	0

ELECTRO-METALLURGY.

ELECTROTYPE APPARATUS, for procuring, by galvanic action, perfect fac-similies of engraved copper-plates, however elaborate; also, correct copies of medals, seals, plaster casts, and all kinds of metallic ornaments.



Horne's Single-Cell Apparatus, suitable for copying medals, coins, seals, plaster casts, &c., &c., with printed directions for use, 5s.—7s. 6d.—10s. 6d. each.

This apparatus is most convenient and simple in its operation, and particularly adapted for those commencing this interesting and useful art.

White earthenware jar, with porous pot, zinc, and wire, 1s. 6d.

Ditto, larger, with binding screw connections, from 5s.

Battery and Precipitating Trough, for making a number of small medals at one time, from £1 5s.

Ditto ditto, larger, £1 17s. 6d.

Vertical Precipitating Trough, with Battery, on Mr. Smee's plan, for obtaining duplicates of engraved copper or other plates, large medals, &c. &c., from £3 8s.,

Electro Gilding and Plating Apparatus, from £1 1s.

Porous Tubes of all sizes.

Binding screws of every description.

Sulphate of copper, 8d. per lb.

Pure plumbago, 6d. per oz.

Sulphuric Acid, 3d. per lb.

Pure silver foil and wire, for precipitation, 10s. per oz.

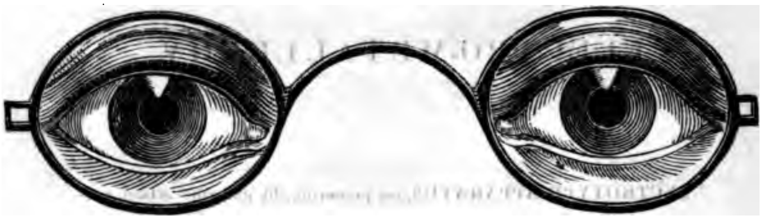
Ditto gold ditto ditto, 6d. per grain.

Ditto platinum ditto ditto, 1d. per grain.

Auro cyanide of potassium, for electro gilding, 8s. per oz. solution.

Argento ditto ditto, for electro plating, 2s. 6d. per oz. solution.

Amalgamated zinc plates of all sizes, at 1s. 6d. per lb.



OPTICAL INSTRUMENTS.

	£.	s.	d.		£.	s.	d.
SPECTACLES of the most improved description—							
Best Gold fitted with Brazil pebble . from	3	10	0	to	4	4	0
Common do. Best glasses . „	1	5	0		2	2	0
Best Standard Silver . . . „	0	12	0		1	5	0
Best Blue Steel . . . . . „	0	10	0		0	18	0
Common do. . . . . . . „					0	2	6
Tortoiseshell . . . . . „	0	8	0		1	0	0
Common Horn and Steel . . „					0	1	6
Wire Gauze Eye Preservers for Railroad Travelling . . . . . . from	0	3	6		0	14	0
Single and Double EYE GLASSES in Gold, Silver, Tortoiseshell, &c., in great variety, from	0	3	6		4	10	0
OPERA GLASSES in a variety of mountings „	2	2	0		10	10	0
Pocket or Military Telescopes, for discovering Objects from 3 to 15 miles . . from	1	10	0		5	5	0

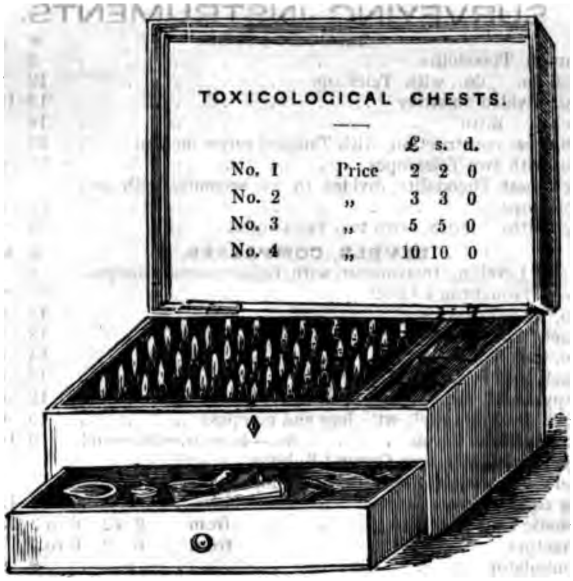
MICROSCOPES.

	£.	s.	d.	£.	s.	d.
Botanical Microscopes with three Powers . .				0	16	0
Flower do do. . . .	0	7	6	0	10	6
Gould's Improved Compound Microscopes, in Case, with Apparatus . . . . from	1	15	0	5	5	0
Very Superior COMPOUND ACHROMATIC MICROSCOPE, with moveable and safety stage, fine adjustment, two eye pieces, and two sets of achromatic object glasses, capable of magnifying from 2,000 to 60,000 times, various apparatus and objects, packed in mahogony cabinet				21	0	0

N.B. This instrument can be much recommended from its cheapness and high magnifying power, combined with extreme sharpness of detail.

	£.	s.	d.	£.	s.	d.
The above on a larger scale, with object glasses of higher power	35	0	0	52	10	0

Polariscopes, Camera Lucidas, Phantasmagoria Lanterns and Slides for Astronomy, and other subjects, &c., &c.



PALMER'S TOXICOLOGICAL CHESTS,

MANUFACTURED ONLY BY HIS SUCCESSORS,

HORNE, THORNTHWAITE, AND WOOD,

123, NEWGATE STREET,

Containing, in stoppered bottles, all the most approved Tests for the detection of Poisons, and a complete set of Apparatus for performing the necessary Experiments, with directions, price Three Guineas; or on a smaller scale, in deal box, price Two Guineas.

TESTIMONIALS.

3, *Hinde Street*, 10*th November*, 1836.

I have examined the Chest of preparations and implements for Toxicological investigations, arranged and sold by Mr. E. Palmer, of 103, Newgate Street; and I have no hesitation in recommending it as well calculated for its purposes, both to the student and practitioner.

ANTHONY TODD THOMPSON,

Professor of Medical Jurisprudence, University of London.

I have examined a Toxicological Chest, fitted up by Mr. Palmer, of Newgate Street, and think it well adapted for the purpose intended, namely, that of enabling students and practitioners to detect Poisons. A Chest of this kind has long been a desideratum. JOHN PEREIRA.

Lecturer on Chemistry at the London Hospital, and at the Aldersgate School of Medisine.

151, Aldersgate Street, Nov. 12, 1836.

SURVEYING INSTRUMENTS.

THEODOLITES.

	£	s.	d.
Common Theodolite.	9	9	0
4-inch do. do., with Telescope	12	12	0
Ditto, divided on silver	13	13	0
5-inch, ditto	18	0	0
Ditto, best construction, with Tangent screw motion.	24	0	0
Ditto, with two Telescopes	36	0	0
6-inch best Theodolite, divided to 20 seconds, with one Telescope	28	0	0
7-inch ditto ditto, with two Telescopes.	42	0	0

LEVELS, COMPASSES, &c.

	£	s.	d.
Portable Levelling Instrument, with Telescope and Compass	8	8	0
14-inch Troughton's Level	11	0	0
Ditto, with Tripod Staff	12	0	0
20-inch Troughton's Level	13	0	0
Ditto, with Tripod Staff	14	0	0
20-inch Y Levels, with Telescope	16	0	0
Dumpy Level, without legs or compass	12	0	0
14-inch Dumpy Level, with legs and compass	15	0	0
Common Spirit Levels . . 3s.—4s.—5s.—6s.—and	0	10	0
Spirit Levels, with best Ground Bubbles			
Miners' Magnetic Compasses, in mahogany cases, with folding sights, from	1	15	0
Prismatic Compasses . . . from 2 12 6 to	3	13	6
Protractors . . . from 0 2 6 to	7	7	0
Perambulator	9	9	0
Ditto, brass mounted	12	0	0
Ditto, ditto, and metal wheel	14	0	0
Station Staffs . . . from	2	15	0
Surveying Crosses or Squares . . from 12s. to	1	11	6
Cylindrical, ditto. . . from 18s. to	1	12	0
Circumferentors . . . from £2 12s. 6d. to	6	6	0
Plane Tables. . . . from £5 10s. 0d. to	12	12	0
Measuring Chains . . . from	0	10	0

Plotting, Marquois, Gunter's Scales and other Rules.

DRAWING INSTRUMENTS.

		£	s.	d.		£	s.	d.
In Fish Skin Cases, in sets,	from	0	7	6	to	2	2	0
Magazine Sets, in mahogany cases,	from	2	10	0	to	18	18	0
Proportional Compasses	from	1	13	0	to	5	5	0

N.B.—Every other description of Instrument used in practical Surveying.

ASTRONOMICAL INSTRUMENTS.

ACHROMATIC TELESCOPES.

	£	s.	d.
18-inches long, with rack and pinion, on stand	8	8	0
Ditto ditto, in German silver	14	14	0
30-inch ditto	12	12	0
Ditto, with vertical rack	14	14	0
Ditto, with vertical and horizontal rack	21	0	0
Ditto, with finder and micrometer	23	10	0
42-inch, with rack and pinion	30	0	0
Ditto, with vertical rack	32	0	0
42-inch, with vertical and horizontal rack-work movement, Finder and Micrometer	36	0	0
Ditto, with equatorial stands, . . . extra	30	0	0
Telescopes, from 5 to 7 feet, with all the recent improvements, . . . from £100 to	300	0	0

The whole of the above astronomical telescopes are furnished with two-day powers and two or more astronomical powers, and are packed in cases.

REFLECTING TELESCOPES, &c.

One-foot Gregorian reflecting Telescope, ou stand, packed in mahogany case, speculum 9½ inches diameter	6	6	0
One-foot and a half ditto, speculum 3 inches diameter .	11	11	0
Two-feet ditto, speculum 4 inches diameter . . .	16	16	0
Ditto ditto, with rack-work motion	25	0	0
Three-feet ditto, with speculum 5 inches diameter, and rack-work motion	42	0	0
Ditto ditto, with speculum 6 inches diameter, on tripod stand, and rack-work motion	68	0	0
Four-feet ditto ditto, with speculum 7 inches diameter .	105	0	0
Seven-feet Newtonian Telescope, with speculum 6 inches diameter	105	0	0
Ditto ditto, with speculum 7 inches diameter . .	126	0	0
Nine-feet ditto, with speculum 9 inches diameter . .	210	0	0
Transit Instruments, ... from £20 to	180	0	0

Micrometers, &c., &c.

NAUTICAL INSTRUMENTS.

QUADRANTS, SEXTANTS &c.

	£	s.	d.		£	s.	d.
Ebony Quadrants	2	5	0	to	3	3	0
Ditto ditto, with Tangent screw . .					3	10	0
Ditto ditto, with Telescopes . . from	4	4	0		6	6	0
Ebony Sextants, best					7	7	0
Metal Sextants, on the most improved principle	7	7	0		12	12	0
Ditto of the best possible construction, divided to 15sec. or 30sec., with apparatus, &c., in case, ... from	12	12	0		18	18	0
Artificial Horizons . . . . . ,,	2	2	0		5	5	0
Cabin and Binnacle Compasses	1	10	0		5	5	0
Azimuth Compasses	4	4	0		10	10	0
Universal and Ring Dials . . from	1	5	0		5	5	0

Pocket Compasses, of every description.

METEOROLOGICAL INSTRUMENTS.

BAROMETERS, &c.

Best Wheel Barometers . . . . from	3	3	0	to	10	10	0
Upright ditto . . . . ,,	1	10	0		7	7	0
Marine ditto . . . . . . ,,	3	3	0		6	6	0
Standard Barometers of the best construction					12	12	0
Improved Simpisometer					3	3	0
Day and Night Self-Registering Thermometers	1	1	0		1	10	0
Sixes's ditto ditto . . . . . from	1	5	0		2	2	0
Thermometers of all descriptions . . ,,	0	2	6		5	0	0
Hygrometer (Daniell's)					2	5	0
Ditto, (Mason's)					2	10	0
Pluviometers . . . . . . from					1	10	0

Foreign Orders, &c. enclosing a remittance or order for payment, in England, promptly attended to.

MERCHANTS SUPPLIED ON LIBERAL TERMS.